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An Investigation of the Effects of Hull Proportion and Step Depth on the Hydrodynamic Characteristics of Flying-Boat Hull Models with Varying Length-Beam Ratio

by

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Prepared For:

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AN INVESTIGATION OF THE EFFECTS OF HULL PROPORTION AND STEP DEPTH ON THE HYDRODYNAMIC CHARACTERISTICS OF FLYING-BOAT HULL MODELS WITH VARYING LENGTH-BEAM RATIOS

for

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TABLE OF CONTENTS

SUMMARY

This report presents the results of "general" tests on the hydrodynamic characteristics of a family of flying-boat hull models. The purpose of these model tests was to explore higher length-beam ratio hulls than were previously investigated, and to investigate the effects of forebody-afterbody proportion and step depth on the hydrodynamic characteristics of hulls with varying length-beam ratio.

The results of this investigation indicate that for loading conditions approximating those of current practice, increasing hull fineness causes relatively minor changes in the hydrodynamic characteristics when the hulls are compared on either the basis of constant planform area ($K_{3/2}$), or the basis of constant length^2-beam product (K_2').

When the sternpost angle is held constant, the optimum forebody-afterbody ratio does not change with hull fineness. On the basis of the resistance characteristics in the displacement and hump speed regions and the lower stability limit properties, the shortest forebody length tested (55 percent of the length, forepoint to sternpost) is slightly better for each of the length-beam ratios considered ($L/b = 6$, 8, and 10). Further studies should be undertaken utilizing a wider range of forebody-afterbody ratios within variations in hull fineness, to determine with certainty whether still longer afterbodies are advantageous.

To obtain the most effective overall spray, resistance and longitudinal stability characteristics, the step depth in percent of beam should be increased with length-beam ratio. The series of models used in this study was constructed so that increase in step depth is accompanied by a corresponding increase in sternpost angle. It is now known that the effects attributed to step-depth change are mostly caused by sternpost angle variation. Step depth as an independent variable (i.e., with constant sternpost angle) has its major effects on the skipping characteristics which were not investigated here. The sternpost angle occurring with the best step depth for each length-beam ratio is the same, 8.9 degrees.

INTRODUCTION

In previous length-beam ratio studies, which utilized hull families arbitrarily expanded from a conventional design having a ratio of approximately 6, every effort was made to isolate rigorously the effects of length-beam ratio as an independent parameter. The past studies did not attempt to discover whether the relative importance of other major hull-shape variables would change when the length-beam ratio was changed.

Fundamentally, of course, there is no reason to suppose, for example, that for optimum performance, the forebody-afterbody length ratio of a hull with an overall ratio of 6 should be the same when the overall ratio is increased to 10, since forebody and afterbody serve different functions. Accordingly, it was believed that fundamental hydrodynamic information should be obtained by testing a series of hull models with various length-beam ratios, using a range of step depths and forebody-afterbody length ratios for each length-beam ratio.

Model tests were made on a related series of flying-boat hulls encompassing three length-beam ratios, three step depths, and three forebody-afterbody length ratios. It appeared unnecessary to test all 27 of the possible combinations of these variables so that only 21 were actually investigated. To put the tests on a comparable basis, all of the hull models were considered to be underbodies for a single aerodynamic structure.

All tests were of the "general" type, covering a wide range of practicable hull loadings. Collapsing methods previously developed made it possible to employ an abbreviated test program and to report all the results for each model on one compact summary chart.

Because of the abbreviated test programs, the investigation of the "peak" of the lower trim limit of stability was not detailed. More complete information in this region can easily be obtained by running additional tests, and this is now being undertaken under a

separate contract. Results will be presented in a supplementary report.

The investigation which forms the subject of this report was authorized by the National Advisory Committee for Aeronautics, under Contract No. NAw 3688, dated September 15, 1944.

DEFINITION OF TERMS

The coefficients and terms used in this report are defined as follows:

Load Coefficient	$C_\Delta = \Delta/wb^3$
Static Load Coefficient	$C_{\Delta_o} = \Delta_o/wb^3$
Speed Coefficient	$C_V = V/\sqrt{gb}$
Resistance Coefficient	$C_R = R/wb^3$
Trimming Moment Coefficient	$C_M = M/wb^4$
Longitudinal Spray Coefficient	$C_X = X/b$
Lateral Spray Coefficient	$C_Y = Y/b$
Vertical Spray Coefficient	$C_Z = Z/b$
Draft Coefficient	$C_d = d/b$
Pitch Damping Coefficient	$M_q/ V \frac{\rho_w}{2} b^4$
Comparison Criteria	$K_2 = \Delta_o/ wL^2b$
	$K_{3/2} = \Delta_o/ wL^{3/2}b^{3/2}$
	$K_{5/2} = \Delta_o/ wL^{5/2}b^{1/2}$

where,

Δ = load on water at any speed, lb.

Δ_o = static load on water, lb.

w = specific weight of water, lb./cu.ft.
(w = 62.3 lb./cu.ft. in these tests)

b = beam at main step centroid, ft.

V = speed, ft./sec.

V_g = getaway speed, ft./sec.

g = acceleration of gravity, ft./sec.^{2}
(g = 32.2 ft./sec.^{2} in these tests)

R = resistance, lb.

M = trimming moment, lb.ft.

X = longitudinal position of main spray point of tangency to the blister envelope, measured fore and aft of the main step centroid, ft.

Y = lateral position of main spray point of tangency to the blister envelope, measured at right angles to and from the hull centerline, ft.

Z = vertical position of main spray point of tangency to the blister envelope, measured from the tangent to the forebody keel at the main step, ft.

d = maximum draft of hull, ft.

ρ_w = mass density of water, lb.sec.^{2}/ft.^{4}
(ρ_w = 1.935 lb.sec.^{2}/ft.^{4} in these tests)

ρ_a = mass density of air, lb.sec.^{2}/ft.^{4}
(ρ_a = 0.002378 lb.sec.^{2}/ft.^{4} in these tests)

M_q = aerodynamic pitch damping rate (contribution of horizontal tail only), lb.ft.sec./rad.

k = radius of gyration in pitch about CG, ft.

L = length of hull, forepoint to sternpost, ft.

L_f = length of forebody, forepoint to step centroid, ft.

L_{oa} = length overall, ft.

The air drag of the model, but not of the apparatus, is included in the water resistance. Moment data are referred to the center of gravity, and water trimming moments which tend to raise the bow are considered positive.

The trim angle, τ, is the angle between the tangent to the forebody keel at the step, and the horizontal.

MODELS

The lines of the parent model for the family were developed from a lengthened forebody version of the PB2Y-4 hull. This resulted in a parent hull having a length-beam ratio of 6 and a forebody length 58 percent of the distance from forepoint to sternpost. Forward of the step centroid, the cross section of the forebody is constant for a length equal to 133 percent of the beam and has a deadrise of 22.5 degrees. The parent has a 30° V-step, with a step depth at the keel of 8 percent of the beam. The afterbody has a constant deadrise of 22.5 degrees and an afterbody angle of 7 degrees. The body plan and profile of the parent model are shown on pages 35 and 36, respectively. This model is designated 6-58-8: the first numeral indicating length-beam ratio, the second group indicating the length of forebody in percent of total length (from forepoint to sternpost), the third group indicating step depth at the keel in percent of beam.

Six variations of this model, all with a length-beam ratio of 6, were made in the manner indicated by the chart of models on page 34. When increasing or decreasing the forebody length, the same length of forebody flat was maintained, and the forward forebody stations were spread apart or squeezed together. Changes in hull proportion were, in fact, a moving aft or forward of the main step. The afterbody stations were held the same distance aft of station zero as in the parent form and were merely raised or lowered to obtain the necessary step height. No change was made in the afterbody planform within any particular length-beam ratio group.

The middle model of the group with length-beam ratio 8, designated 8-58-10.66, had a forebody length of 58 percent of the total length and a step depth at the keel of 10.66 percent of the beam. Six variations of this model were made as shown by the chart of models on page 34. For all the models of length-beam ratio 8, the region of constant cross section, or forebody flat, was equal to 100 percent of the beam.

The middle model of the length-beam ratio 10 group, designated

10-58-13.33, had a forebody length of 58 percent of the length from forepoint to sternpost and a step height of 13.33 percent of the beam. In this group, the forebody flat was equal to 66 percent of the beam. As shown by the chart of models on page 34, six variations of this model were made.

When increasing or decreasing the forebody length within a given length-beam ratio, the method used was the same as that described for the length-beam ratio 6 models. For the hulls with higher length-beam ratios, the station spacing of the parent was uniformly increased over that part of the forebody forward of the region of constant section, and over the whole of the afterbody.

The scale ratios of the hulls in different length-beam ratio groups cannot be determined until a suitable definition of size is introduced. According to one definition, hulls of different length-beam ratio can be said to have the same size when their length^2-beam products are the same. If this definition of size is adopted, and the 1/30 scale model of the XPB2M-1 flying boat ($L/b = 6.19$; $b = 5.40"$; $\Delta_o = 6.07$ lb.) is used as the basis for comparison, than all the models of different length-beam ratios will have the same size when their length^2-beam products are 6042 in.^{3}. If this is so, the beams for the models with length-beam ratios of 6, 8, and 10 will be 5.52 inches, 4.55 inches, and 3.92 inches respectively, as shown by the upper set of figures on page 10. For convenience in testing, however, all models were constructed with a 5.4 inch beam, altering the scale ratio of each length-beam ratio group. The scale ratios for the 6, 8, and 10 length-beam ratio groups can be found to be 1/30.7, 1/25.3 and 1/21.8 respectively.

Since the different length-beam ratio groups are related by virtue of a constant length^2-beam product and constant gross weight, they can be considered to be a variation of hull form to be substituted under one hypothetical airplane design. Consequently, when expanding the parent to length-beam ratios greater than 6, the following conditions were maintained:

1) the intersection of keel and chine at the bow was held

at approximately the same height above the baseline for the full-scale hulls (Reference 1),

2) the depth of step, in percent of beam, was increased with increasing length-beam ratio to hold the step depth approximately constant as the beam decreased,

3) the length of forebody flat, in percent of beam, was decreased with increasing length-beam ratio to help offset the increase in trim of the lower stability limits accompanying high length-beam ratio hulls.

The test results may have been affected somewhat by altering the amount of forebody flat in direct proportion to changes of length, since forebody warping is known to have an independent effect (Reference 7).

Body plans and profile lines for the parent models of the L/b = 8 and L/b = 10 groups are on pages 37 through 40. The body sections for these two groups are the same as those for the L/b = 6 parent except that the chine is higher forward, resulting in greater deadrise angles at the bow.

All 21 models, as built, are identical in the following respects:

1) a 30° V-planform step,
2) a beam of 5.40" at the step centroid,
3) the beam, measured at the chine, at corresponding stations,
4) the forebody keel height at corresponding stations,
5) the forebody deadrise angle in the region of constant cross section and a constant afterbody deadrise angle of 22.5°,
6) an afterbody angle of 7°,
7) the center of gravity located 35 percent of the beam forward of the step centroid and 90 percent of the beam above the forebody keel. (This location is the same as that used in an investigation of a Standard Series of hull models for the Bureau of Aeronautics).

Pertinent model hull particulars are tabulated on page 33.

TESTS

Model Design Characteristics and Scope of Tests

For a series of models of varying length-beam ratio, incorporating systematic changes of shape emanating from a single "parent" form, previous studies (Reference 2) indicate that at least the resistance and spray characteristics are approximately the same when the beam loading coefficient is proportional to the square of the length-beam ratio, i.e., $C_{\Delta_o} = K_2(L/b)^2$*. The normal beam loading coefficients for the varying length-beam ratio hulls is this study are based on a constant K_2 value of 0.028. This value is derived from the XPB2M-1 flying boat ($L/b = 6.19$) at a gross load of 165,000 pounds. When a constant K_2 value is used, size differences between the various length-beam ratio hulls are eliminated by holding the length^2-beam product constant, as discussed on page 7.

The design characteristics of a 1/30-scale model of the XPB2M-1 are tabulated on page 10. The second set of figures give the design characteristics of the hulls in the three length-beam ratio groups considered here, derived on a constant L^2b product basis. By using this basis, size is eliminated as a factor and the various length-beam ratio hulls have the same scale, 1/30. Although these hulls have different length-beam ratios, each could be substituted as the hull of a hypothetical model air structure having the same scale and gross weight as the XPB2M-1 model. Also, each model hull would be expected to have the same tail damping rate, M_q/V, as the XPB2M-1. The value of the radius of gyration, K, was derived for each model by making it directly proportional to the overall length including the tail cone. The only change in overall length is that of the forebody. Because of the similarity of dimensions, the radius of gyration for the model designated 6-55 was assumed to be the same as that of the XPB2M-1 model.

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* This can be written $K_2 = \dfrac{\Delta_o}{wL^2b}$

DESIGN CHARACTERISTICS OF THE MODELS

L/b	L_f/L %	L in.	b in.	Δ_o lb.	C_{Δ_o}	L^2b_3 in.	K_2	I_p lb.in.^{2}	k in.	k/L	M_q/V $\frac{\text{lb.sec.}^2}{\text{rad.}}$	$\frac{M_q}{V\frac{\rho_m}{2}b^4}$	L_f in.	ΔL_f in.	L_{oa} in.	Scale
XPB2M-1 Model																
6.19	55.5	33.44	5.40	6.07	1.07	6042	0.028	343	7.52	.225	9.94×10^{-3}	0.249	18.60	0	49.60	1/30
Constant L^2b, Constant K_2																
6.00	55 58 61	33.10	5.52	6.07	1.00	6042	0.028	343 367 371	7.52 7.77 7.82	.227 .235 .236	9.94×10^{-3}	0.229	18.20 19.20 20.20	0 1.00 2.00	49.20 50.20 51.20	1/30
8.00	55 58 61	36.40	4.55	6.07	1.80	6042	0.028	370 385 401	7.80 7.96 8.13	.214 .219 .223	9.94×10^{-3}	0.494	20.00 21.10 22.20	1.80 2.90 4.00	51.00 52.10 53.20	1/30
10.00	55 58 61	39.20	3.92	6.07	2.80	6042	0.028	392 410 428	8.03 8.21 8.39	.205 .209 .214	9.94×10^{-3}	0.897	21.55 22.75 23.90	3.35 4.55 5.70	52.55 53.75 54.90	1/30
Constant b, Constant K_2																
6.00	55 58 61	32.40	5.40	5.69	1.00	5670	0.028	308 330 333	7.36 7.62 7.65	.227 .235 .236	9.10×10^{-3}	0.229				1/30.7
8.00	55 58 61	43.20	5.40	10.25	1.80	10700	0.028	876 917 953	9.25 9.46 9.64	.214 .219 .223	19.65×10^{-3}	0.494				1/25.3
10.00	55 58 61	54.00	5.40	15.90	2.80	15746	0.028	1954 2030 2122	11.08 11.29 11.55	.205 .209 .214	35.60×10^{-3}	0.897				1/21.8

The third set of tabulated figures give the actual design characteristics for the constant beam models used in the tests. Changes from the second set of figures are due, simply, to changes in the scale ratios of the models.

Ranges of loading coefficient for the several models were selected on the basis of past practice as analyzed in Reference 3. The pertinent data from Reference 3 and the C_{Δ_o} values used in the present investigation are reproduced on the chart on page 43. The chart shows that the ranges of load coefficient vary approximately with the equation $C_{\Delta_o} = K_2(L/b)^2$.

The mean getaway speed coefficients for the various hulls tested are based on a getaway speed coefficient of 7.00 for the XPB2M-1 at 165,000 pounds. Since present day trends are toward higher take-off speeds, a range of getaway speed coefficients from 5.00 to 11.00 was taken for the XPB2M-1.

The tabulation below summarizes the ranges of loading coefficient and getaway speed coefficient for the several models:

L/b		6.00	8.00	10.00
C_{Δ_o}	High	1.40	2.50	3.80
	Normal	1.00	1.80	2.80
	Low	0.60	1.10	1.80
C_{V_g}	High	11	12	13
	Mean	6.9	7.6	8.2
	Low	5	5.5	5.9

The relationship

$$C_\Delta = C_{\Delta_o}\left[1 - \left(\frac{C_V}{C_{V_g}}\right)^2\right]$$

was used in determining the load fall-off curves of net water-borne

load versus speed. The unloading curves shown on page 44 are for the hulls having a length-beam ratio of 8.

Test Apparatus and Procedure

The apparatus and procedures used in making this series of tests were those generally employed at the Experimental Towing Tank during tests for:

Main Spray (References 4 and 5),
Resistance (Reference 6),
Longitudinal Stability (References 6, 7, and 8),
Static Properties.

The apparatus described in these references were those used for testing in the original towing basin designated as Tank No. 1. As soon as they were available, the additional facilities provided by the new 300-foot towing basin, designated as Tank No. 3, were also employed.

The towing apparatus used in Tank No. 3 (see pages 41 and 42) is designed in such a way that both resistance and stability tests can be made with the same apparatus. For resistance tests, the model is allowed freedom of trim and heave. The part of the apparatus to which the model is attached is allowed limited straight-line horizontal motion. This part is suspended from the carriage by Watt links and is connected to a dynamometer for measuring the resistance. When stability tests are made, the horizontal motion is prevented. The data for these tests are obtained on smoked glass slides as described in Reference 6.

The procedure followed in making resistance and longitudinal stability tests in Tank No. 3 are the same as those described in the references given above for equipment used in Tank No. 1.

Static properties can be determined using either the Tank No. 3 apparatus or the Tank No. 1 resistance apparatus. The model is subjected to various water-borne loads, and the corresponding trims and drafts for each load are determined.

The data included here were obtained by the "general" method of testing flying-boat hull models. The term "general" is used in

the same sense in which it is ordinarily employed by the NACA in connection with resistance tests (see Reference 9). It was necessary to use this method because no single water-borne load or trim (even if these were made functions of speed) could be established as representative for a given flying boat. In addition, it was possible, by using the general method, to simplify test programs and so expedite the accumulation of data.

The lines of the models were supplied in groups, first those of length-beam ratio 8, then 6, and finally 10. A Stevens Note (Reference 10), giving the preliminary results for each group, was released as soon as the work on each group, was completed. Since the results were required as rapidly as possible, it seemed more efficient to complete the tests on all the designated models, rather than to delay the experimental work in order to compare the results of a few selected hulls in an attempt to reduce further the number of models in the series.

PRESENTATION OF RESULTS

To simplify the presentation of the hydrodynamic characteristics investigated and to make it as compact and all-embracing as possible, the spray, resistance and longitudinal stability results are presented in collapsed form on pages 66 through 86 as a one-sheet summary report for each model. Each chart is divided into three parts and shows:

1) at the top -- Dimensions of the Spray Blister Envelopes for free-to-trim tests at displacement speeds, in accordance with method of presentation developed in Reference 5.

2) in the middle -- Resistance and Trim Angles for free-to-trim tests at displacement speeds, in accordance with the method of presentation developed in Reference 6. A curve is shown for each C_Δ, since no basis has been found for collapsing the resistance results in this speed range.

3) at the bottom -- Resistance and Stability Characteristics at planing speeds, in accordance with the methods of presentation developed in References 6 and 8. The curves represent the data for all values of C_Δ and trim covered by the tests.

The purpose of the summary chart is simply to present a complete report on one model. It does not represent the end result ultimately desired in standard series work - namely, to show the effect of form variations from model to model. The importance of the summary chart is that it clears the way for a direct consideration of the trends to be revealed in a standard series study.

For clarity, moment data are omitted from the summary charts and are plotted separately in nondimensional form on pages 87 through 107. These charts present moment coefficients at the trims and load-speed combinations $(\sqrt{C_\Delta}/C_V)$ at which they occur throughout the planing range. Because the data are so scattered around the hump, no attempt has been made to draw curves through the plotted points.

The static properties are presented on pages 108 through 128.

These charts show how the draft coefficient, C_d, varies with trim τ, and load coefficient, C_Δ, for zero moment. On pages 63 through 65, are static properties charts for Model No. 685 (10-58-13.33) showing the variation of draft and trim with changes in center of gravity position.

EFFECT OF HULL SHAPE VARIABLES

Two groups of comparisons are made. First, models with varying length-beam ratio are compared to determine the effect of length-beam ratio on the hydrodynamic characteristics. Second, models with the same length-beam ratio are compared to determine the effects of forebody-afterbody length ratio and step depth on the hydrodynamic characteristics.

Effect of Length-Beam Ratio

The influence of length-beam ratio on the hydrodynamic characteristics of a flying-boat hull cannot be determined until differences of "size" are eliminated. This may be done by using equations of the type

$$C_{\Delta_o} = K_n (L/b)^n$$

or, in a more useful form,

$$K_n = \frac{\Delta_o}{wL^n b^{3-n}}$$

with n greater than zero but not greater than 3. It will be noted that, for any value of n, K will eliminate size as a factor and is, in fact, a substitution for C_{Δ_o} as the criterion for comparisons between hulls.

For the present discussion, three values of n are chosen on the basis of the results in previous reports relating to the influence of length-beam ratio on hydrodynamic characteristics (References 2, 11, and 12). The first, $n = 3/2$, is used to compare hulls on the basis of constant load on a given planform area. On this basis, all hulls have the same draft. The second, $n = 2$, is used to compare hulls on the basis of equal seaworthiness, assuming that a hull is satisfactorily seaworthy when loaded to half of the load required to sink it when it is running in waves at low speeds (Reference 13). The third, $n = 5/2$, is used to compare hulls on the basis of draft being a constant per-

centage of forebody length. When the draft at the step, expressed as a constant proportion of the length of the forebody is taken as the criterion, the British (Reference 12) define the seaworthiness as being equal.

In order to determine the effect of length-beam ratio on the hydrodynamic characteristics, three hulls with different length-beam ratios were selected for comparison on bases of constant $K_{3/2}$, K_2, and $K_{5/2}$. The purpose of making the comparison on three different bases was to show the relative effect of these bases on the characteristics of the hulls. The models chosen were:

Model No.	Designation	Sternpost Angle
654	6-58-8	9.0°
634-03	8-58-10.66	8.9°
685	10-58-13.33	8.9°

The effects of forebody-afterbody hull proportion and sternpost angle (varies when step height and length-beam ratio are varied) were minimized by choosing approximately similar hulls with respect to these design features. Step depth, when treated as an independent variable (i.e., with constant sternpost angle), has its major effects on the skipping characteristics of flying-boat hulls which were not considered here.

The loadings used in the comparisons are based on a K_2 of about 0.024 which is in agreement with present design loadings, while the loads used for the tests are based on a nominal K_2 of 0.028. Because of the wide range of loads included in the tests, enough data were available to make the conversion.

The three models were treated as three different hull versions for a full-size airplane with a gross load of 115,250 pounds and a wing area of 2100 sq.ft. (unloading curve shown on comparison charts, pages 45 through 47). For comparison on a constant $K_{3/2}$ basis, the design characteristics of the three models were computed from the full-size figures to be:

L/b	L in.	b in.	Δ_o lb.	C_{Δ_o}	$(Lb)^{3/2}$ in.^{3}	$K_{3/2}$
6	32.94	5.49	5.12	0.86	2430	.0584
8	38.00	4.75	5.12	1.33	2430	.0584
10	42.50	4.25	5.12	1.85	2430	.0584

To obtain the design characteristics of the three models for comparison on a constant K_2 basis, the same full-size design characteristics were used and the hull with L/b = 6 taken as the base boat:

L/b	L in.	b in.	Δ_o lb.	C_{Δ_o}	L^2b in.^{3}	K_2
6	32.94	5.49	5.12	0.86	5957	.0238
8	36.24	4.53	5.12	1.52	5957	.0238
10	39.10	3.91	5.12	2.37	5957	.0238

In a like manner the design characteristics of the three models were determined for comparison on a constant $K_{5/2}$ basis, the L/b = 6 model again being the base boat:

L/b	L in.	b in.	Δ_o lb.	C_{Δ_o}	$L^{5/2}b^{1/2}$ in.^{3}	$K_{5/2}$
6	32.94	5.49	5.12	0.86	14560	.00974
8	34.59	4.32	5.12	1.76	14560	.00974
10	35.80	3.58	5.12	3.08	14560	.00974

On pages 45 through 47, the principal hydrodynamic characteristics of the three selected hulls are compared on the bases of $K_{3/2}$, K_2, and $K_{5/2}$. The comparison charts show that the beam loading cannot be increased in proportion to the 5/2 power of the length-beam ratio without sacrifice in some of the major hydrodynamic characteristics (in this instance, longitudinal stability and main spray), and that the choice lies somewhere between $K_{3/2}$ and K_2.

Moment versus trim curves for a speed near take-off and a speed near the hump are shown on page 48 for the three different

length-beam ratio hulls on both the constant K_2 and $K_{3/2}$ bases.

Moment stability limits are shown on page 49 for the three different length-beam ratio hulls on bases of constant K_2 and $K_{3/2}$. At each speed, the applied pitching moment which causes a 2 degree oscillation in trim angle is called a moment stability-limit point.

If the length^2-beam product (K_2), percentage of forebody length and sternpost angle are held constant, increasing length-beam ratio:

a) lowers the resistance and trim at speeds below the hump,
b) has little effect on high speed resistance,
c) reduces the stable range of trim angles,
d) raises the main spray blister (although this is due, partly, to differences in forebody warping),
e) increases the stable range of pitching moments at high speeds (near take-off),
f) increases the "stiffness" of the hull (less change in trim per inch-pound of moment).

Effect of Forebody-Afterbody Length Ratio and Step Depth

To determine the effect of increasing the percentage of forebody to total length (forepoint to sternpost) for the length-beam ratios considered, three models from each of the three length-beam ratio groups are compared on a constant planform area ($K_{3/2}$) basis. (Since only hulls having the same length-beam ratio are compared, it does not matter what K_n is used.) The three groups of models compared are listed below. These particular hulls were selected because their sternpost angles are very nearly the same. In this way sternpost angle, which is known to affect trim, is eliminated as a variable.

	Model No.	Designation	Sternpost Angle
Group I	656	6-55-6	8.4°
	653	6-58-6	8.5°
	658	6-61-6	8.6°
Group II	642	8-55-8	8.3°
	633	8-58-8	8.4°
	644	8-61-8	8.5°
Group III	674	10-55-10	8.3°
	689	10-58-10	8.4°
	687	10-61-10	8.5°

Comparisons of the principal hydrodynamic characteristics for the models selected are on pages 50 through 55. If the planform area, length-beam ratio, step depth and sternpost angle are held constant, increasing the percentage of forebody to total length from 55 to 61 percent:

a) increases the resistance at displacement and hump speeds,

b) raises the free-to-trim track in the displacement and hump speed regions,

c) has no appreciable effect on the lower limit of stability for the groups with length-beam ratios of 6 and 8, but raises the lower limit for the group with length-beam ratio of 10,

d) has a relatively minor effect on the spray envelopes for the length-beam ratio groups of 6 and 8, and indicates no clearly defined tendency for the length-beam ratio 10 groups,

e) has no appreciable effect on the static drafts, but raises the static trims.

Since the step depth in any one length-beam ratio group was varied by raising or lowering the hull afterbody, the sternpost angle increased with step depth. Because step depth is a function of sternpost angle, the effects which are attributed to step depth variations could be more accurately ascribed to sternpost angle changes. Some

step depth comparisons, including effects on the spray, resistance, longitudinal stability and static properties, are shown on pages 56 through 61. Sternpost angle differences are noted on these comparison charts. Increasing step depth (with a corresponding increase in sternpost angle):

a) raises the upper limit trims,
b) raises the spray height at the step,
c) raises the resistance around the hump,
d) raises the free-to-trim track in the vicinity of the hump,
e) increases the static drafts slightly and raises the static trims appreciably.

In addition to the step depth comparisons discussed above, a study of the model test results was made to determine the best step depth and sternpost angle for hulls with different length-beam ratios. The chart on page 62 was obtained from the results of this study.

As a matter of incidental interest, the center of gravity position was altered on Model No. 685 (10-58-13.33) to determine its effects on the static drafts. The charts on pages 63 through 65 show that changing the location of the center of gravity does not cause any appreciable changes in the static drafts.

DISCUSSION

The manner in which the models are altered when the variables under consideration are changed has an important bearing in apprais-ing the results of a study of the present type. In this instance, the afterbody angle was held constant and changes were made in hull proportion and step depth, in addition to changes in length-beam ratio. Consequently, changes occurred in the sternpost angle. Since variation in sternpost angle affects the hydrodynamic characteris-tics, it is difficult to determine the separate effects of the other variables unless only those models with the same sternpost angle are compared. In addition to the above alterations of form, the forebody flat was decreased as the length-beam ratio was increased. This was done to help offset the increase in trim just beyond the "peak" of the lower stability of high length-beam ratio hulls. Since spray characteristics are affected by length of forebody flat, any compari-son of the effect of length-beam ratio on spray characteristics will also reflect the effect of forebody warping.

As far as possible, an effort is made to exclude secondary ef-fects from comparisons between models of varying length-beam ratio. The three comparisons of specific hulls (shown on pages 45 through 47) demonstrate that increasing the beam loading coefficient, C_{Δ_0}, from a rate proportional to the 3/2 power of the length-beam ratio to a rate proportional to the 5/2 power magnifies the differences in hydrodynamic characteristics between the three different length-beam ratio hulls. Differences in the lower stability limits are especially magnified. The $K_{5/2}$ basis for comparing the hydrodynamic characteristics of varying length-beam ratio hulls increases beam loading with length-beam ratio at a much too rapid rate and, there-fore, discloses great disparities between the characteristics of models with different hull fineness. When either $K_{3/2}$ or K_2 is used as a basis for comparison, there is not a great deal of dissimilarity between the hydrodynamic properties of different length-beam ratio hulls. The one major difference (found when either of the three

bases of comparison is used) is in the lower stability limits, which are influenced by forebody warping. These comparisons show that increasing hull fineness decreases the stable range of trims. However, the moment stability charts on pages 48 and 49 indicate that increasing hull fineness increases the stable range of trimming moments, especially at high speeds, so that the decrease in trim spread between the longitudinal stability limits is partly offset by the greater stiffness of the high length-beam ratio hulls. These factors indicate that for the range of length-beam ratios studied here and for loading conditions approximately those of current practice, increasing length-beam ratio has no large detrimental effects on the principal hydrodynamic characteristics.

Within the range of variation used in this study, the optimum forebody-afterbody length ratio does not change with hull fineness when the sternpost angle is held constant. In practically all instances, increasing the forebody length from 55 to 61 percent of the total length had small adverse effects on the hydrodynamic characteristics. This was most clearly illustrated in the cases of low and hump speed resistance and trim characteristics.

The spray envelopes were not, on the whole, sensitive to changes in forebody proportion. However, the spray envelopes seemed to be more liable to fluctuate with change in forebody proportion with the high length-beam ratio hull groups. When the forebody proportion of total length is increased, the lower stability limits of the groups of models with length-beam ratios of 6 and 8 are unaffected, but for the group of models with the length-beam ratio of 10, the lower limits are raised. The tests indicate that the forebody length 55 percent of total length (forepoint to sternpost) is best for all three length-beam ratio groups investigated, on the basis of the resistance characteristics in the displacement and hump speed regions, and the lower stability limit properties. Further studies should be undertaken using a broader range of forebody-afterbody proportions within variations of length-beam ratio to determine with certainty whether still longer afterbodies are advantageous, as these tests seem to indicate.

Variation of sternpost angle, which was not considered in the original specifications, has an appreciable effect on the hydrodynamic characteristics of flying-boat hulls. The sternpost angles for the hulls in this series are those resulting from a systematic variation of forebody proportion and step depth with constant afterbody angle. Since sternpost angle will affect the static properties, stability limits, and free-to-trim data, changes in these characteristics which are attributed to step depth change are, in reality, largely due to variations of sternpost angle.

Increasing step depth (with a corresponding increase in sternpost angle) will increase the stable range of trims by raising the upper stability limit. However, increasing step depth and sternpost angle also raises the free-to-trim track, with a resulting increase in free-to-trim resistance and spray height at displacement speeds. Therefore, the step depth (and sternpost angle) for different length-beam ratio hull designs must be selected so that a good compromise is reached between longitudinal stability, spray and resistance performance.

The results of the tests indicate that the step depth in percent of beam should be increased as length-beam ratio is increased. The best step depth in percent of beam for the length-beam ratio of 6 models is 8 percent, for the length-beam ratio of 8 models, 10.67 percent, and for the length-beam ratio of 10 models, 13.33 percent. The sternpost angle for each of these three models is the same, 8.9 degrees.

The number of tests run on each model in the series was kept as low as possible by taking every advantage afforded by the methods of collapsing data. In the planing region, data covering a wide range of loading conditions can be represented by a single curve, so that the number of tests made in this range can be limited greatly and the curves still defined accurately (References 6 and 8). Just below planing speeds in the transition region, the lift supplied by the water is partly buoyancy, and the data obtained at various loadings in this vicinity do not collapse. Because resistance charac-

teristics were investigated in both the planing and displacement ranges, sufficient tests had to be made in the displacement and transition regions to determine the curve for each load investigated. There is, therefore, resistance data over the whole speed range, so that it is possible to make specific resistance curves for operating conditions within the range of loads investigated.

Lower limit porpoising tests, however, were insufficient in the transition region. Since the data at various loadings do not collapse in this region, the curves drawn are valid only for the loads and speeds at which they were tested. (The load and speed at which each stability limit point was found may be determined by consulting the moment data charts presented on pages 87 through 107.)

Supplementary tests are being made to determine the "peaks" of the lower limit, at a series of constant loads for the middle hull of each length-beam ratio group. These additional tests will yield a lower stability limit branch for each constant gross load. At planing speeds, the separate branches collapse into a single lower limit curve. With this information it will be possible to obtain specific porpoising limits for operating conditions within the loadings investigated. The results of this study will be reported separately.

CONCLUSIONS

The test results presented here provide a basis for:

A. Clarifying the significance of length-beam ratio as an independent variable,

B. Indicating whether or not the effects of other major hull-shape variables change with variation of length-beam ratio.

The following conclusions are drawn from test data, and apply to the family of models investigated:

1) If the length^2-beam product (K_2), the loading conditions, the forebody length in percent of total length (forepoint to sternpost), and the sternpost angle are held constant, then increasing length-beam ratio
   a) lowers the resistance and trim at speeds below the hump,
   b) has little effect on high speed resistance,
   c) reduces the stable range of trim angles,
   d) raises the main spray blister (although this is due, partly, to differences in forebody warping),
   e) increases the stable range of pitching moments at high speeds (near take-off),
   f) increases the "stiffness" of the hull (i.e., less change in trim per inch-pound of moment).
2) The beam loading cannot be increased in proportion to the 5/2 power of the length-beam ratio without sacrifice in some major hydrodynamic characteristics (e.g., longitudinal stability and main spray in the case considered on page 47). As discussed on page 18, a rate proportional to the 3/2 power of the length-beam ratio is conservative. A rate proportional to the square of the length-beam ratio appears to be maximum, so that the choice lies somewhere between constant $K_{3/2}$ and K_2.
3) For the conditions and limits of this study, there are no large detrimental effects due solely to increase in

length-beam ratio, when the hulls are compared on the basis of the constant K_2 or $K_{3/2}$ load coefficient for loading conditions approximating those of current practice.

4) If the planform area, the loading conditions, the length-beam ratio, and the sternpost angle are held constant, then increasing the forebody percent of total length (forepoint to sternpost) from 55 to 61 percent:

   a) increases the resistance at displacement and hump speeds,
   b) raises the free-to-trim track in the displacement and hump speed regions,
   c) has no appreciable effect on the lower limit of stability for the groups with length-beam ratios of 6 and 8, but raises the lower limit for the group with length-beam ratio of 10,
   d) has a relatively minor effect on the spray envelopes for the length-beam ratio groups of 6 and 8, and indicates no clearly defined tendency for the length-beam ratio 10 group,
   e) has no appreciable effect on the static drafts, but raises the static trims.

5) The optimum forebody proportion does not change with hull fineness when the sternpost angle is held constant. On the basis of the statements in the preceding paragraph (4), it is concluded that a forebody length 55 percent of the total length (forepoint to sternpost) is best for all three length-beam ratio groups investigated.

6) Increasing step depth (with a corresponding increase in sternpost angle)

   a) raises the upper limit trims,

b) raises the spray height at the step,

c) raises the resistance around the hump,

d) raises the free-to-trim track in the vicinity of the hump,

e) increases the static drafts slightly and raises the static trims appreciably.

7) For the models used in this study, an increase in step depth is accompanied by an increase in sternpost angle, as discussed on page 24. It is now known that the effects attributed to step depth change are, to a large degree, due to sternpost angle variation. This study, however, indicates that the step depth in percent of beam should be increased with length-beam ratio; in each length-beam ratio group, the hull with the best overall hydrodynamic characteristics has a sternpost angle of 8.9 degrees. Within the ranges investigated, the best step depth in percent of beam for the length-beam ratio group of 6 is 8 percent, for the length-beam ratio of 8, 10.67 percent, and for the length-beam ratio of 10, 13.33 percent.

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12. Clark, K. W. and Coombes, L. P.: "Tank Tests of a Family of Four Hulls of Varying Length to Beam Ratio", Royal Aircraft Establishment, Farnborough, Report No. BA B50, November 1936.
1330

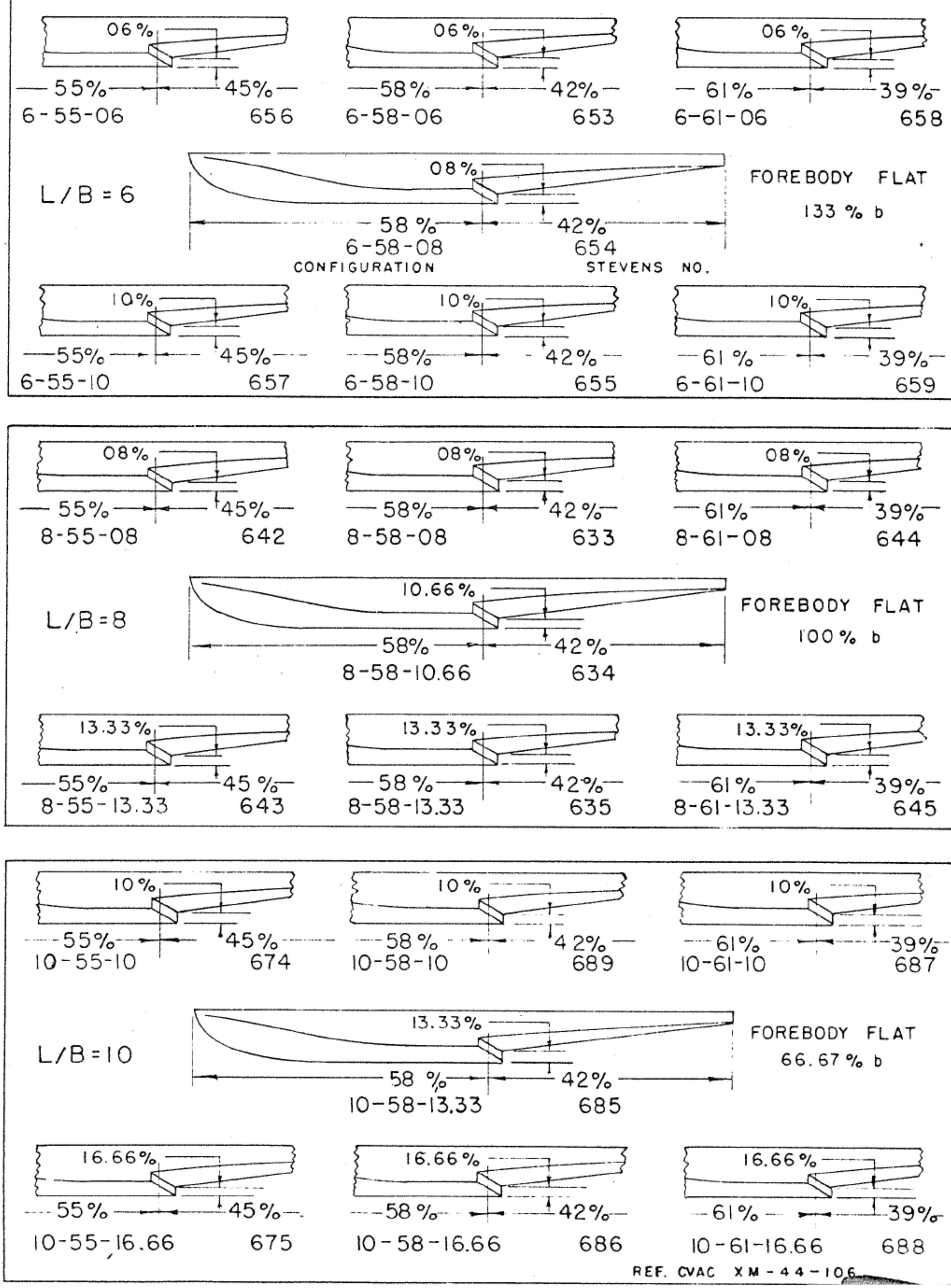
13. Locke, F.W.S., Jr.: "Note on the Design of Flying-Boat Hulls and the Interrelation of C_Δ and L/b", Bureau of Aeronautics, Navy Department, ADR No. T-15, October 1945.

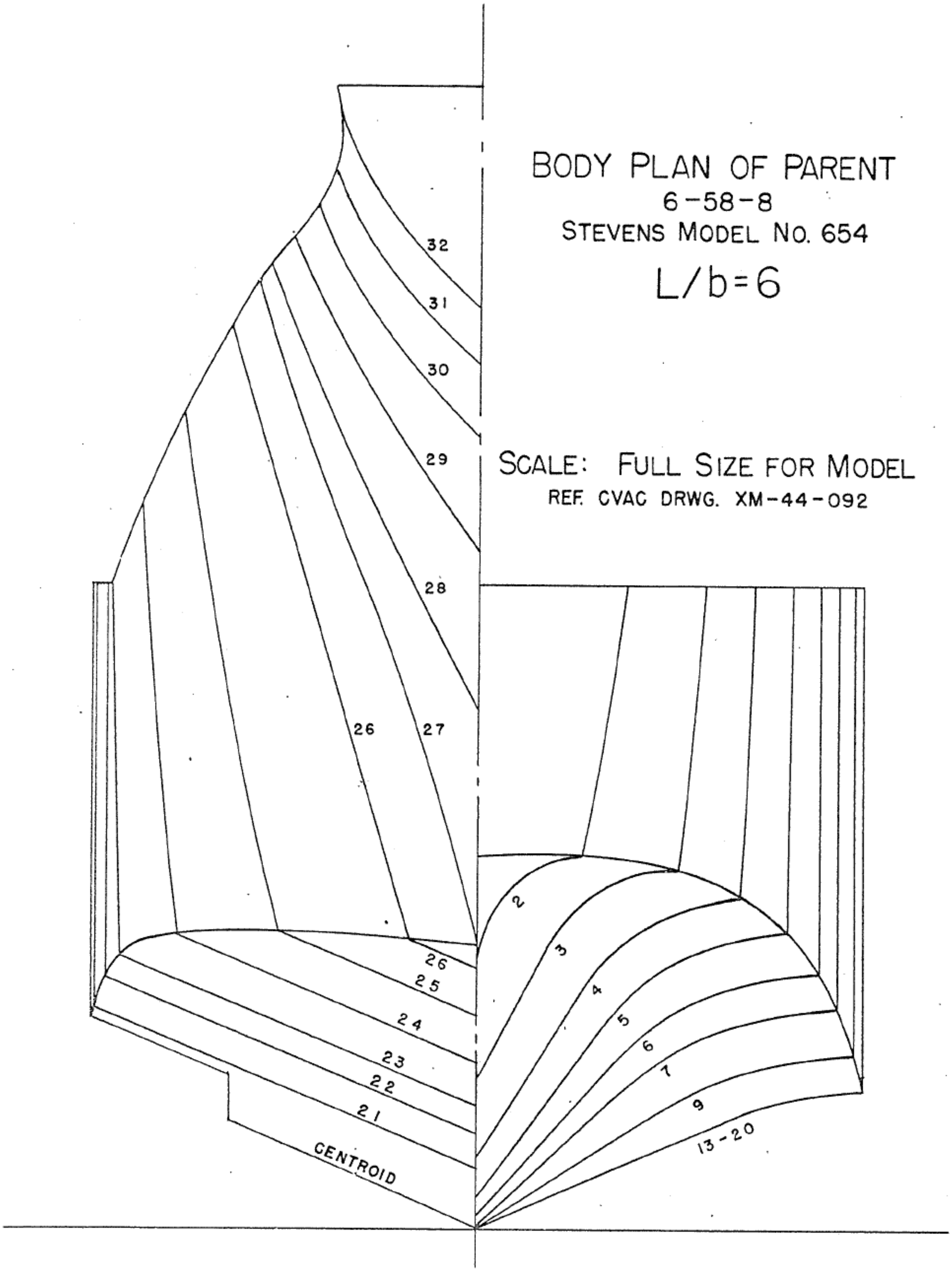
MODEL PARTICULARS

Model	Designation	Hull Lgth. in.	F.B. Lgth. in.	A.B. Lgth. in.	Tail Cone Lgth. in.	F.B. Flat Lgth. in.	Step Height at Keel in.	Step Height at Centroid in.	Stern Post Height in.	Stern Post Angle Deg.
656	6-55-6	32.4	17.82	14.58	14.48	7.20	.32	.20	1.99	8.4
657	6-55-10		17.82	14.58			.54	.41	2.20	9.2
653	6-58-6		18.79	13.61			.32	.20	1.87	8.5
654	6-58-8		18.79	13.61			.43	.30	1.98	9.0
655	6-58-10		18.79	13.61			.54	.41	2.08	9.4
658	6-61-6		19.76	12.64			.32	.20	1.75	8.6
659	6-61-10		19.76	12.64			.54	.41	1.96	9.6
642	8-55-8	43.2	23.76	19.34	15.89	5.40	.43	.30	2.68	8.3
643	8-55-13.33		23.76	19.34			.72	.59	2.97	9.2
633	8-58-8		25.06	18.14			.43	.30	2.53	8.4
634	8-58-10.66		25.06	18.14			.58	.45	2.68	8.9
635	8-58-13.33		25.06	18.14			.72	.59	2.82	9.4
644	8-61-8		26.35	16.85			.43	.30	2.37	8.5
645	8-61-13.33		26.35	16.85			.72	.59	2.66	9.6
674	10-55-10	54.0	29.70	24.30	17.00	3.60	.54	.41	3.40	8.3
675	10-55-16.67		29.70	24.30			.90	.77	3.76	9.2
689	10-58-10		31.32	22.68			.54	.37	3.20	8.4
685	10-58-13.33		31.32	22.68			.72	.54	3.38	8.9
686	10-58-16.67		31.32	22.68			.90	.72	3.56	9.3
687	10-61-10		32.94	21.06			.54	.37	3.00	8.5
688	10-61-16.67		32.94	21.06			.90	.72	3.36	9.5

Beam at Step: 5.40 in.
Deadrise of Forebody Flat and Afterbody: 22.5 deg.
Afterbody Angle: 7 deg.
Length of Step V: 1.56 in.
Step Centroid 1.04 in. forward of apex
CG Location
    Forward of Step Centroid: 1.89 in.
    Above Baseline: 4.86 in.
The sternpost angle is the angle between a line through the sternpost and step apex, and the tangent to the forebody keel at the step.

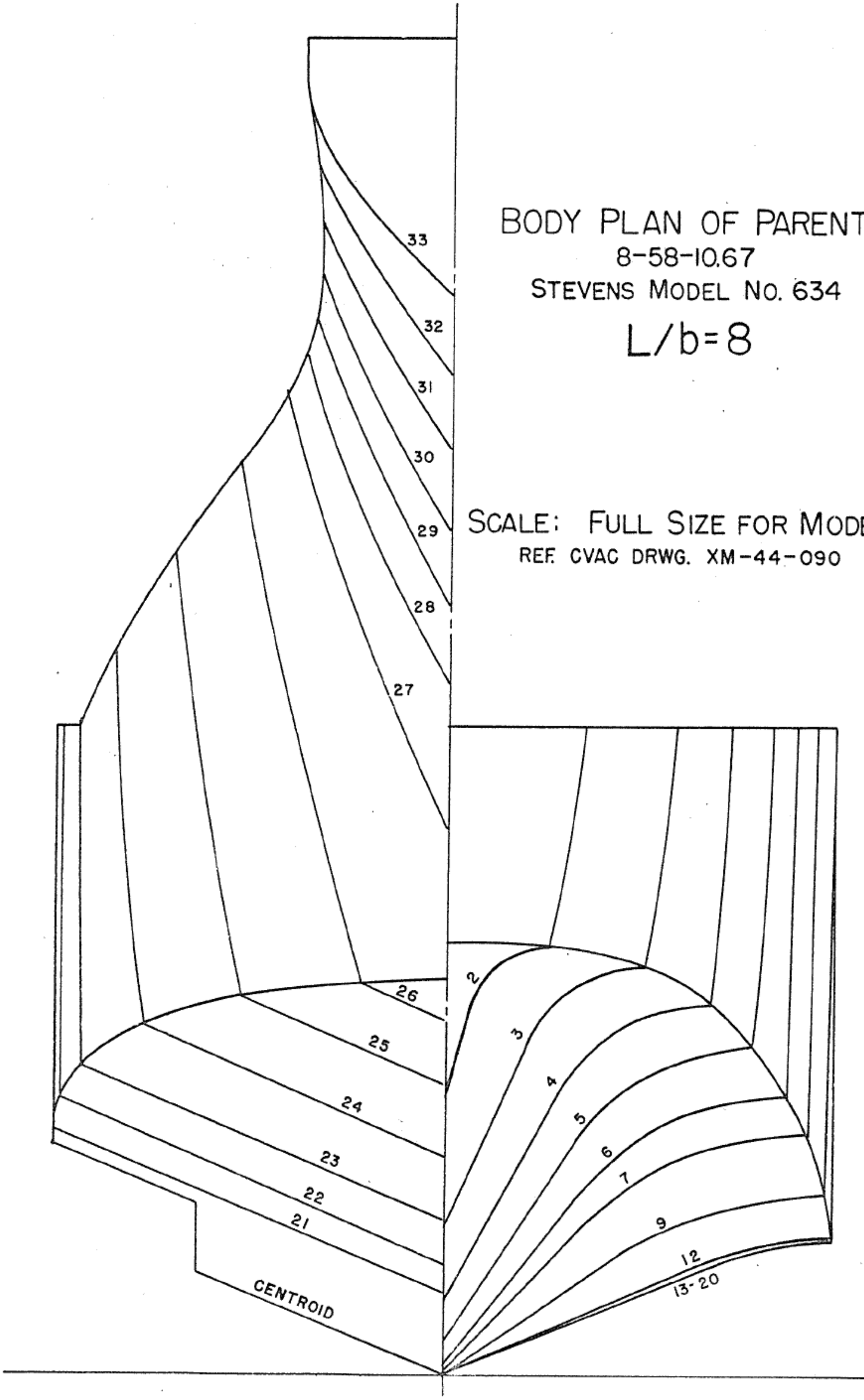
SCHEMATIC DIAGRAMS OF HULLS

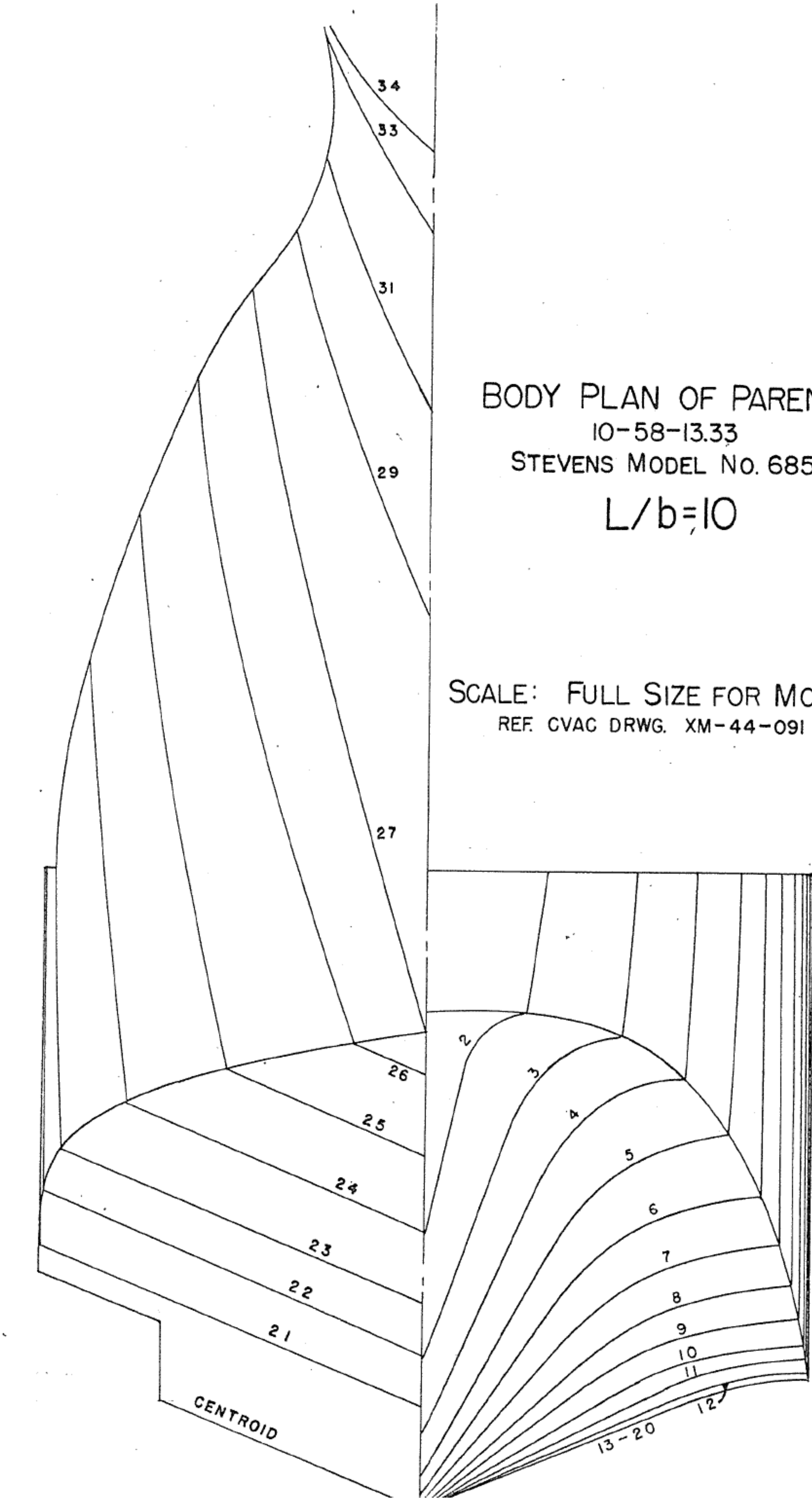



BODY PLAN OF PARENT
6-58-8
STEVENS MODEL NO. 654
L/b=6
SCALE: FULL SIZE FOR MODEL
REF. CVAC DRWG. XM-44-092
32
31
30
29
28
26
27
26
25
24
23
22
21
CENTROID
2
3
4
5
6
7
9
13-20

BODY PLAN OF PARENT
8-58-10.67
STEVENS MODEL NO. 634
L/b=8

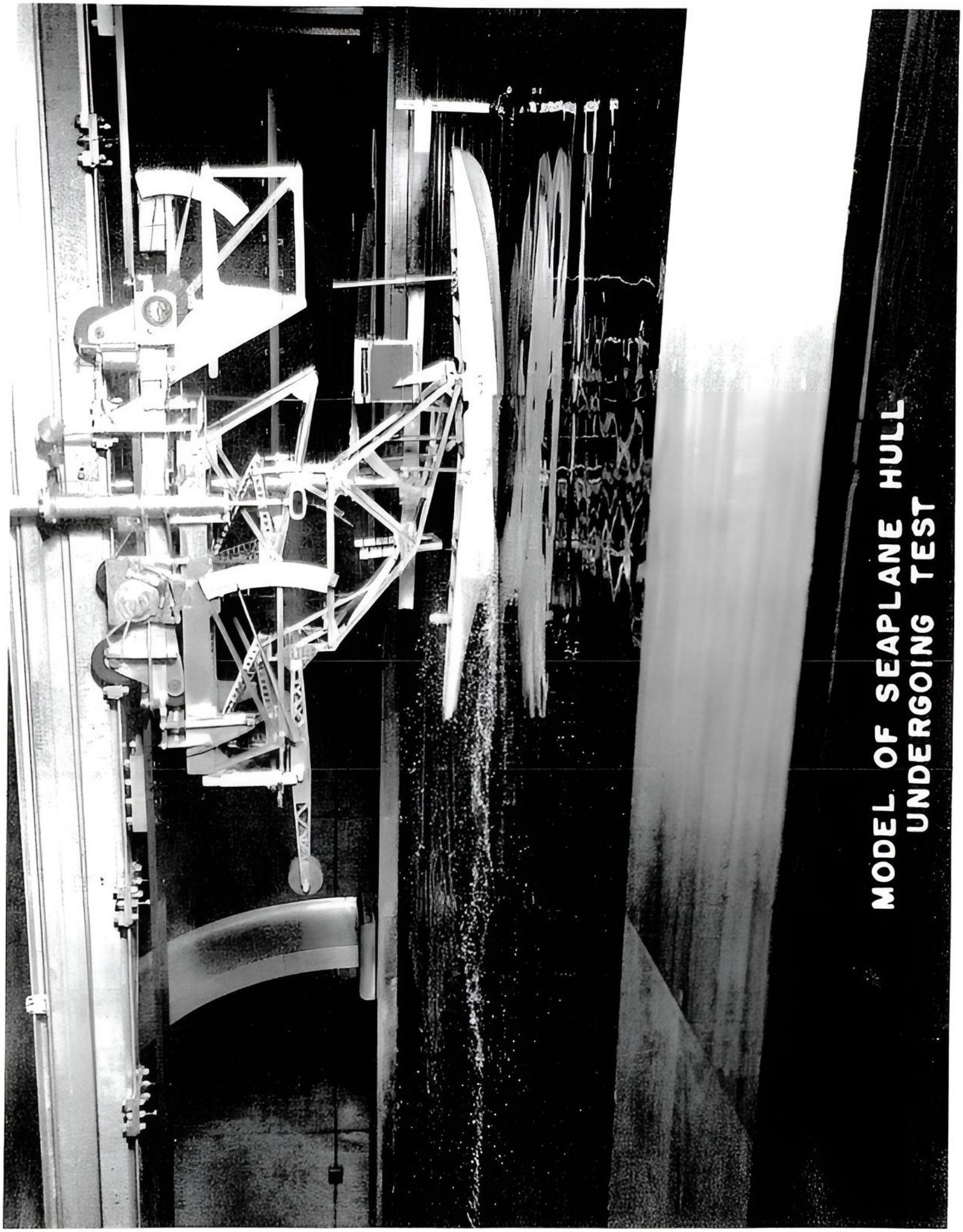
SCALE: FULL SIZE FOR MODEL
REF. CVAC DRWG. XM-44-090



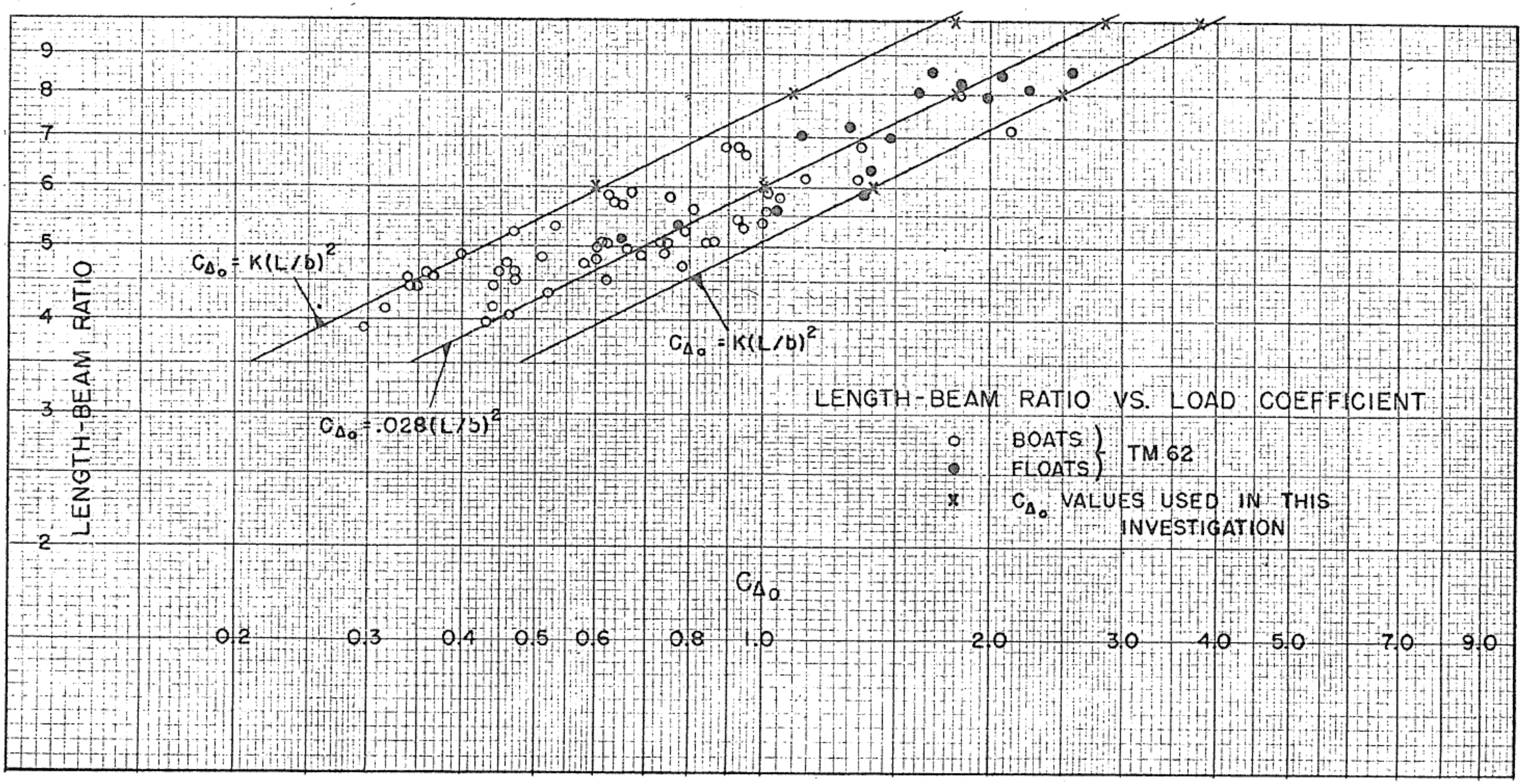


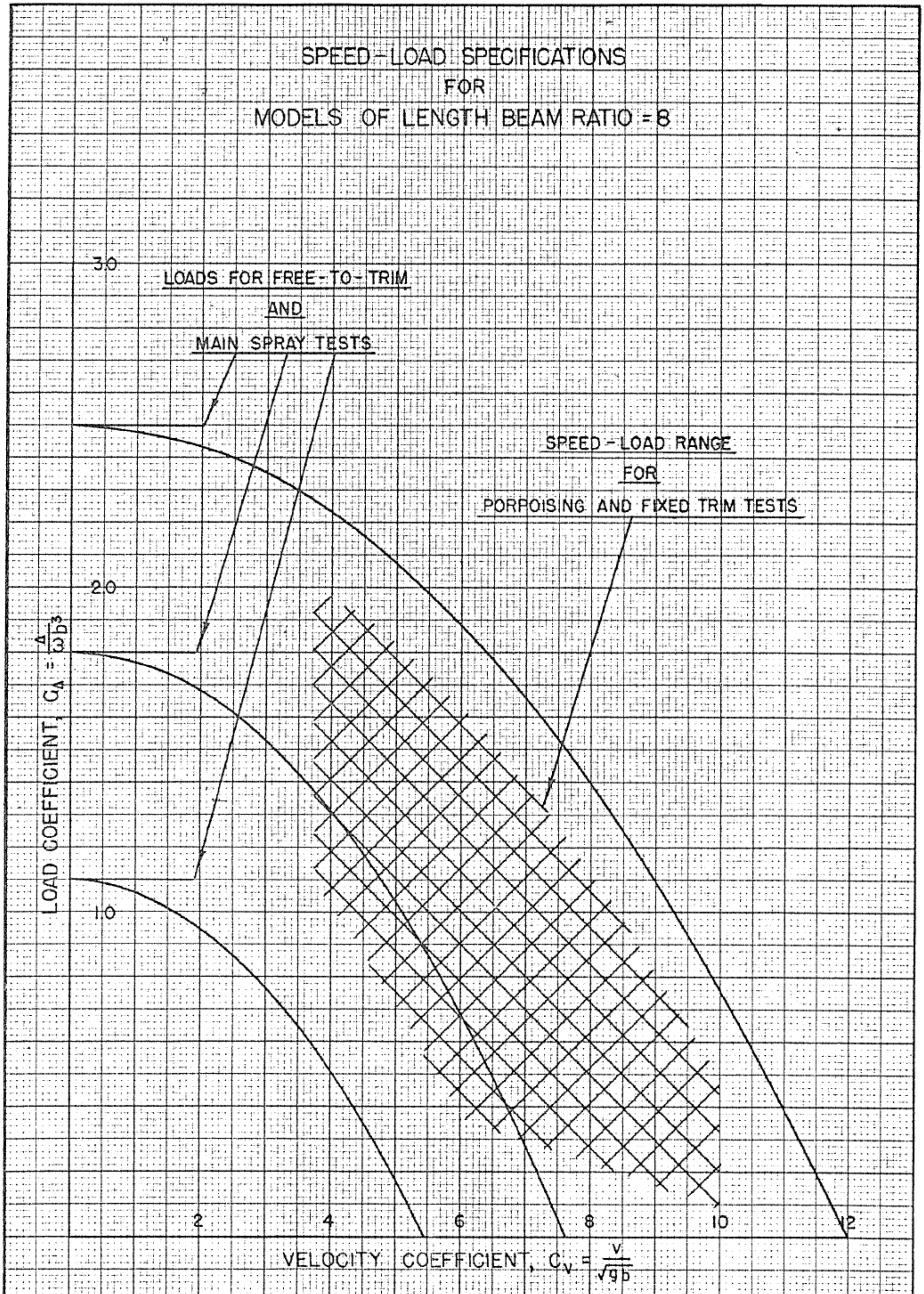
BODY PLAN OF PARENT
10-58-13.33
STEVENS MODEL NO. 685
L/b=10

SCALE: FULL SIZE FOR MODEL
REF. CVAC DRWG. XM-44-091


MODEL OF SEAPLANE HULL
UNDERGOING TEST

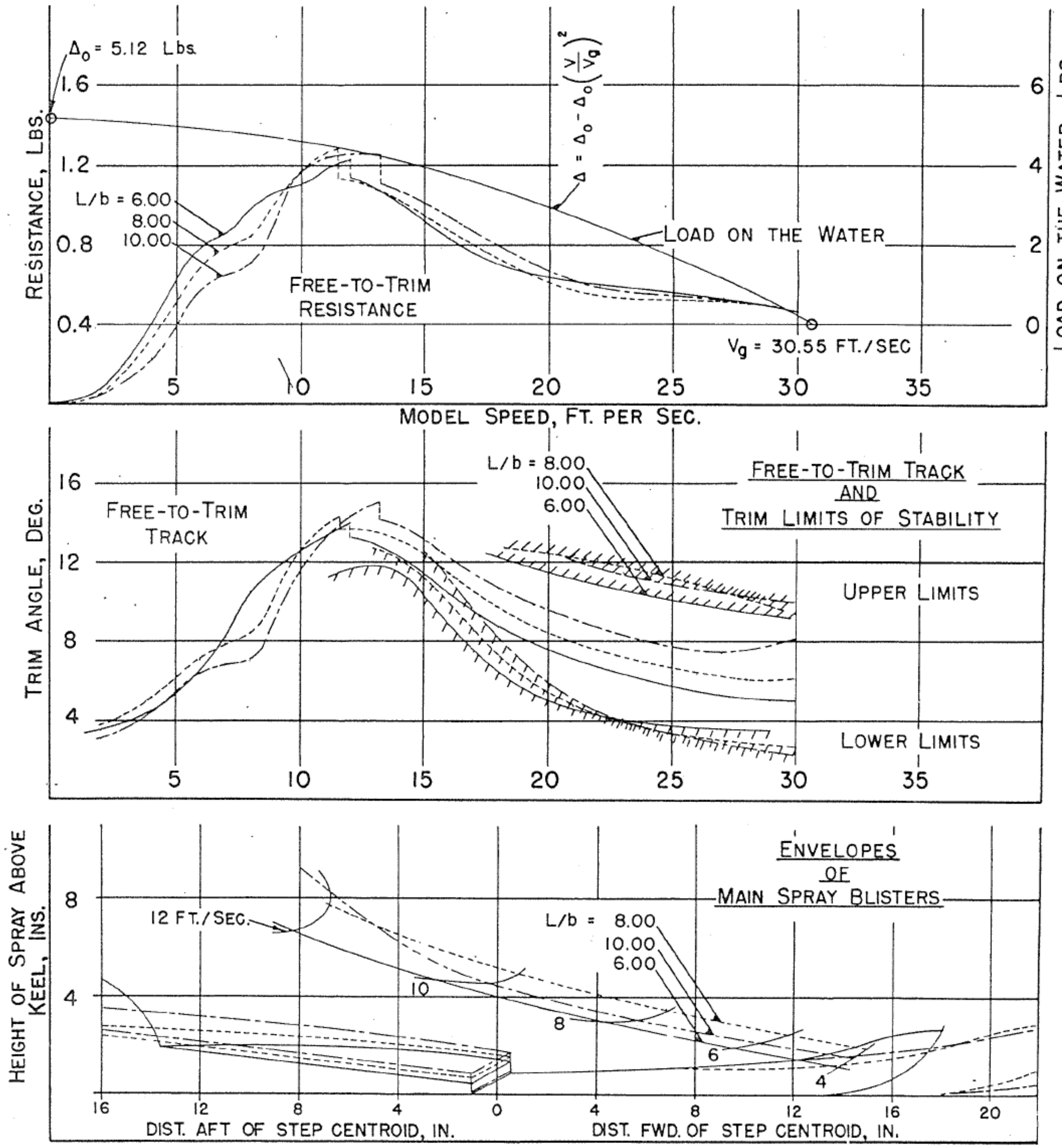
DOCK END OF TANK


LENGTH-BEAM RATIO VS. LOAD COEFFICIENT
BOATS
FLOATS
TM 62
C_{Δ_0} VALUES USED IN THIS INVESTIGATION
$C_{\Delta_0} = K(L/b)^2$
$C_{\Delta_0} = .028(L/b)^2$
$C_{\Delta_0} = K(L/b)^2$
LENGTH-BEAM RATIO
C_{Δ_0}
0.2
0.3
0.4
0.5
0.6
0.8
1.0
2.0
3.0
4.0
5.0
7.0
9.0
2
3
4
5
6
7
8
9


SPEED-LOAD SPECIFICATIONS
FOR
MODELS OF LENGTH BEAM RATIO = 8
LOADS FOR FREE-TO-TRIM
AND
MAIN SPRAY TESTS
SPEED-LOAD RANGE
FOR
PORPOISING AND FIXED TRIM TESTS
LOAD COEFFICIENT, $C_\Delta = \frac{\Delta}{\omega b^3}$
VELOCITY COEFFICIENT, $C_V = \frac{V}{\sqrt{gb}}$
3.0
2.0
1.0
2
4
6
8
10
12

HYDRODYNAMIC CHARACTERISTICS OF THREE MODELS OF DIFFERING LENGTH-BEAM RATIO WITH CONSTANT PLANFORM AREA ($K_{3/2}$)

L/b	L	b	C_{Δ_0}	LINE SYMBOL
6.00	32.94"	5.49"	0.86	———
8.00	38.00"	4.75"	1.33	-------
10.00	42.50"	4.25"	1.85	—-—-—

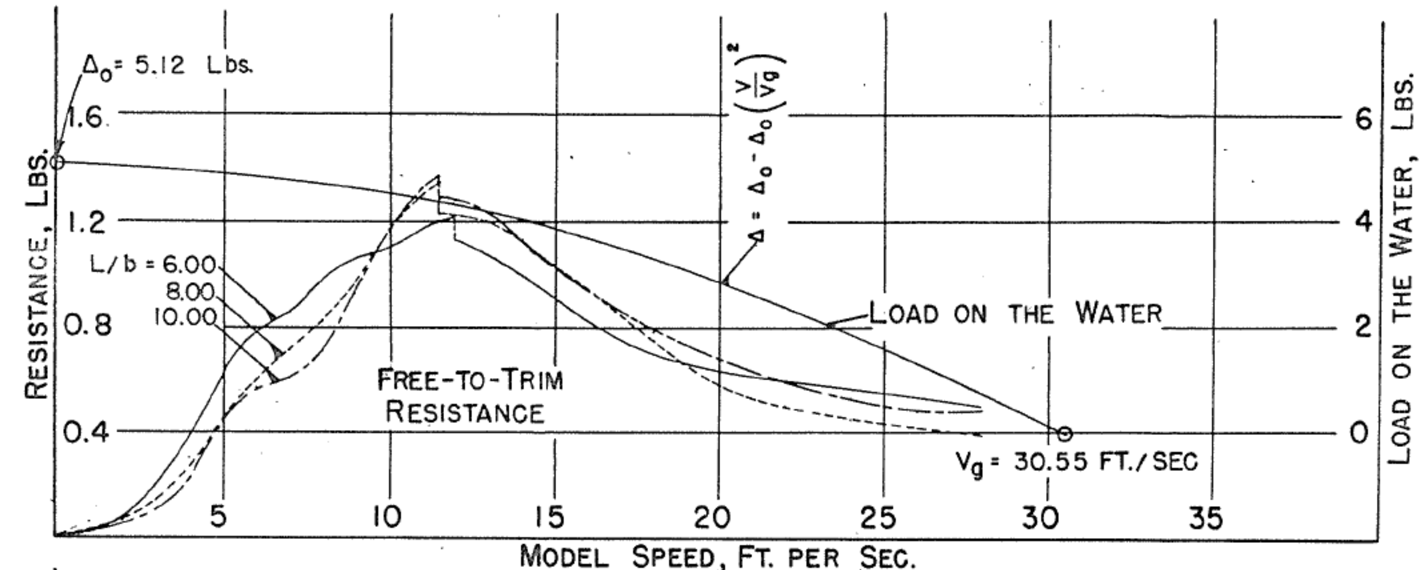


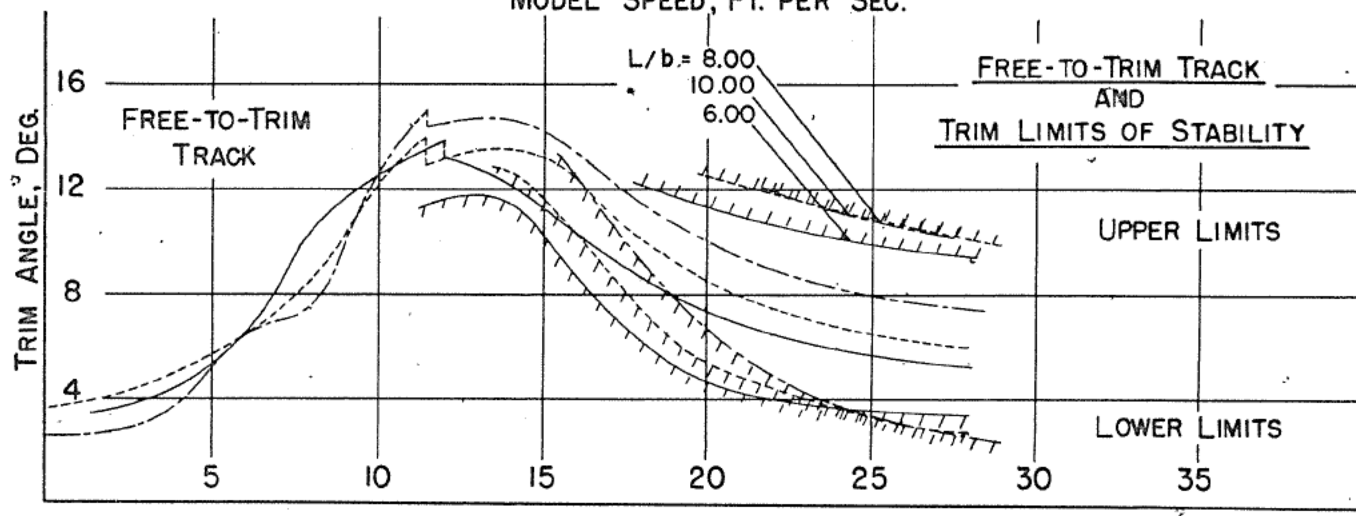
LOADING COEFFICIENTS

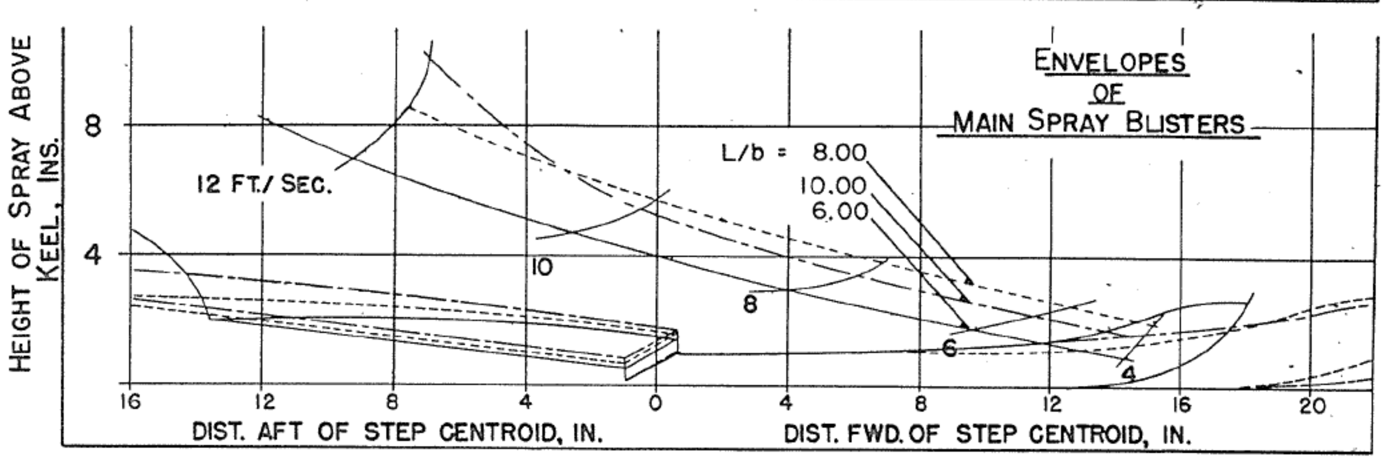
L/b	6.00	8.00	10.00
C_{Δ_0}	0.86	1.33	2.15
$K_{3/2}$ (CONSTANT)	0.058	0.058	0.058
K_2	0.0238	0.0207	0.0185

HYDRODYNAMIC CHARACTERISTICS OF THREE MODELS OF DIFFERING LENGTH-BEAM RATIO WITH CONSTANT $L^2b(K_2)$

L/b	L	b	C_Δ	LINE SYMBOL
6.00	32.94"	5.49"	0.86	———
8.00	36.24"	4.53"	1.52	------
10.00	39.10"	3.91	2.37	—·—·—





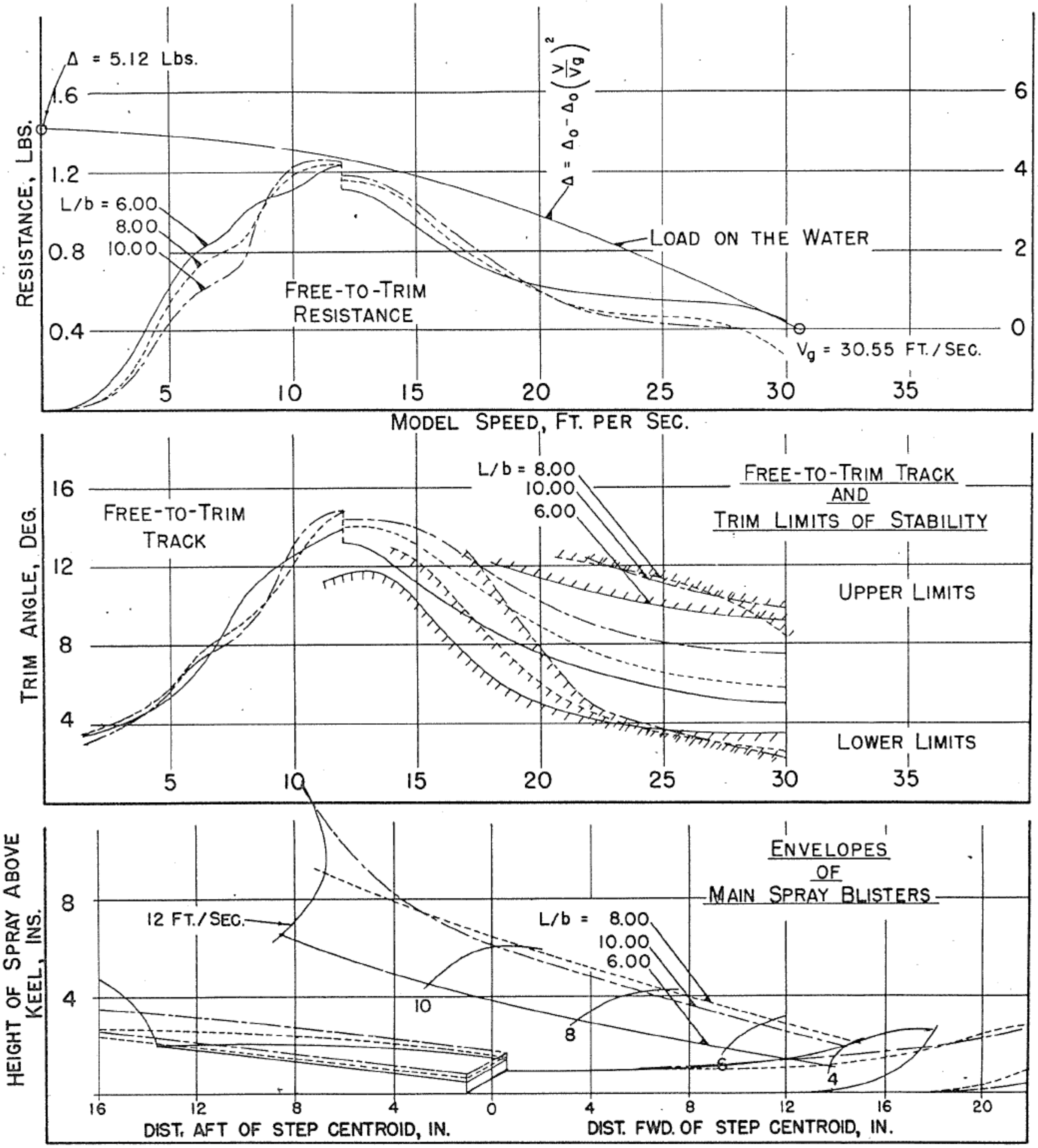


LOADING COEFFICIENTS

L/b	6.00	8.00	10.00
C_{Δ_0}	0.86	1.52	2.37
K_2 (CONSTANT)	0.0238	0.0238	0.0238
$K_{3/2}$	0.058	0.067	0.075

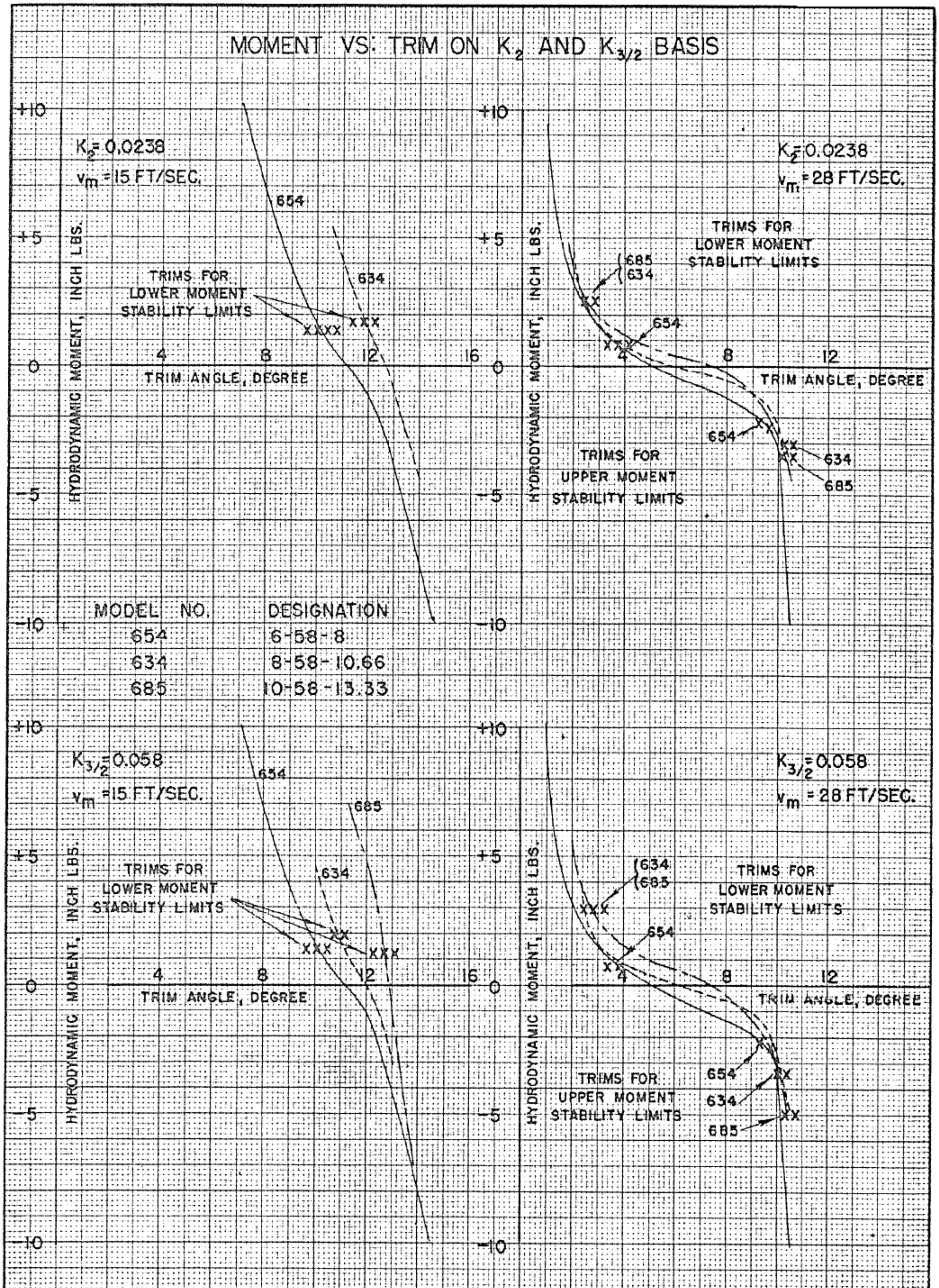
HYDRODYNAMIC CHARACTERISTICS OF THREE MODELS OF DIFFERING LENGTH-BEAM RATIO WITH CONSTANT $L^{2.5}\ b^{0.5}\ (K_{2.5})$

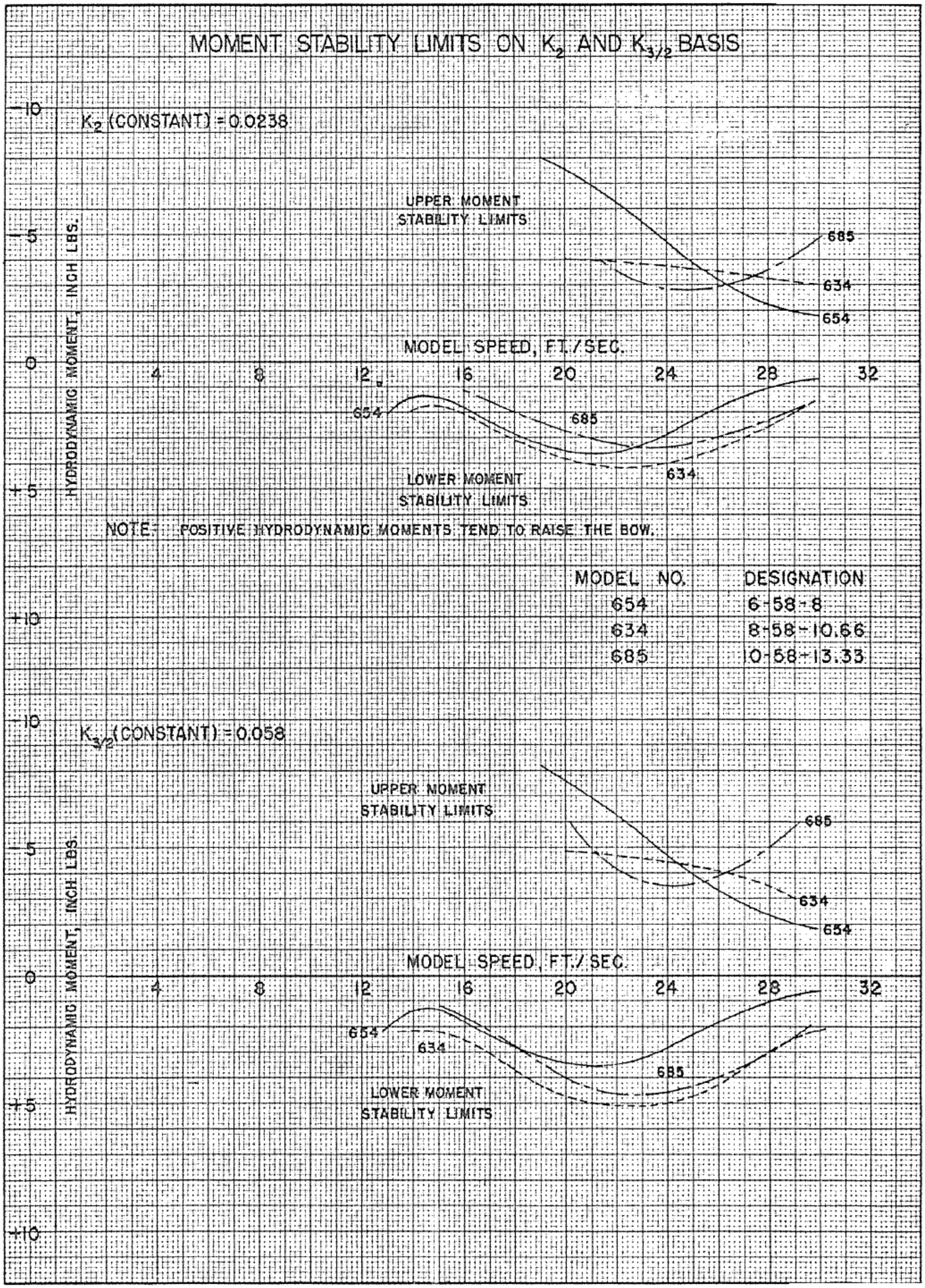
L/b	L	b	C_{Δ_0}	LINE SYMBOL
6.00	32.94	5.49	0.86	———
8.00	34.59	4.32	1.76	- - - - -
10.00	35.80	3.58	3.08	— - — -



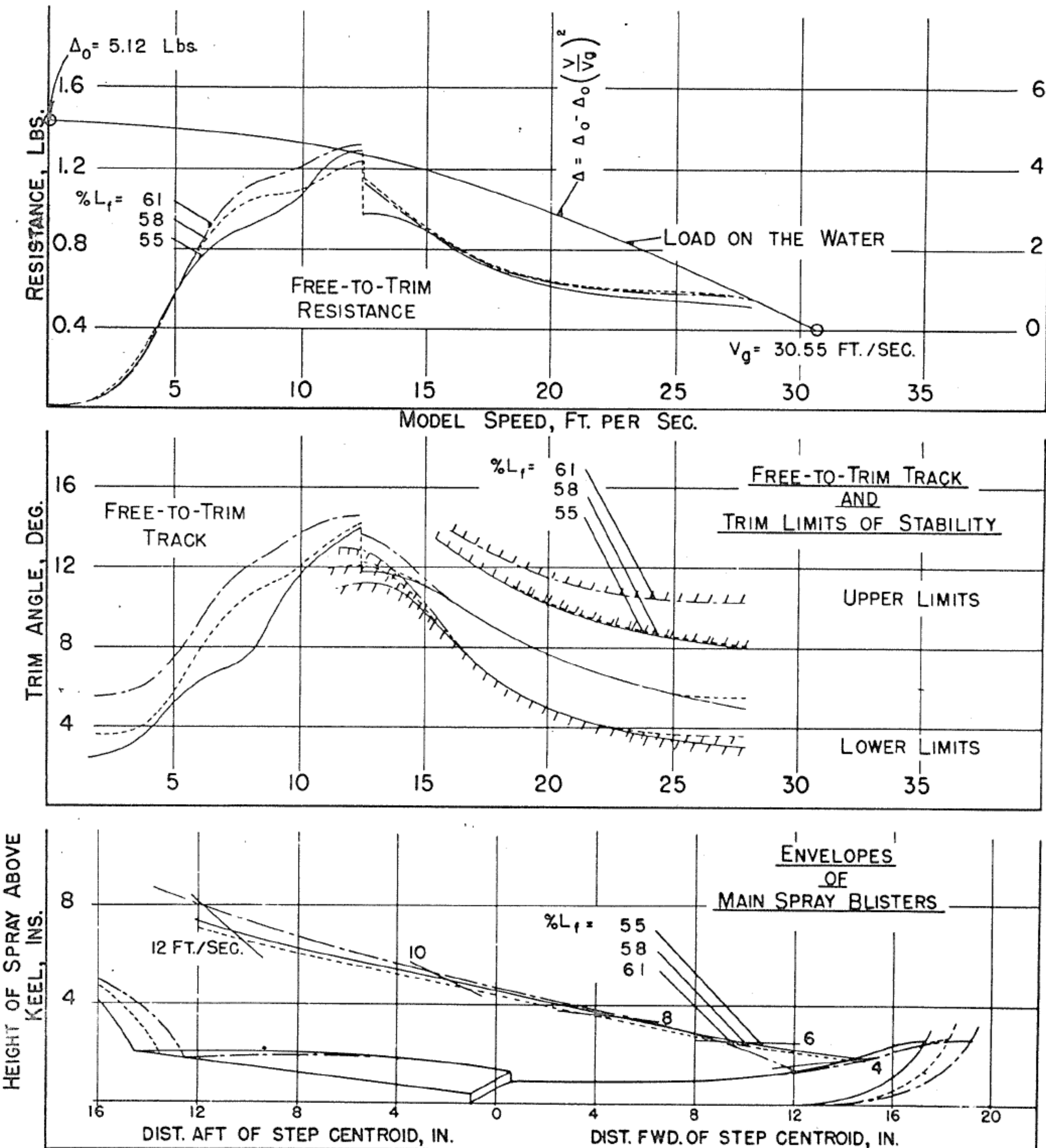
LOADING COEFFICIENTS

L/b	6.00	8.00	10.00
C_{Δ_0}	0.86	1.76	3.08
$K_{2.5}$ (CONSTANT)	0.0097	0.0097	0.0097
K_2	0.0238	0.0275	0.0308


MOMENT VS. TRIM ON K_2 AND $K_{3/2}$ BASIS
K_2 = 0.0238
v_m = 15 FT/SEC.
K_2 = 0.0238
v_m = 28 FT/SEC.
HYDRODYNAMIC MOMENT, INCH LBS.
TRIM ANGLE, DEGREE
TRIMS FOR LOWER MOMENT STABILITY LIMITS
TRIMS FOR UPPER MOMENT STABILITY LIMITS
654
634
685
MODEL NO. DESIGNATION
654 6-58-8
634 8-58-10.66
685 10-58-13.33
$K_{3/2}$ = 0.058
v_m = 15 FT/SEC.
$K_{3/2}$ = 0.058
v_m = 28 FT/SEC.


MOMENT STABILITY LIMITS ON K_2 AND $K_{3/2}$ BASIS
K_2 (CONSTANT) = 0.0238
UPPER MOMENT STABILITY LIMITS
685
634
654
MODEL SPEED, FT./SEC.
0
4
8
12
16
20
24
28
32
-10
-5
+5
+10
HYDRODYNAMIC MOMENT, INCH LBS.
654
685
634
LOWER MOMENT STABILITY LIMITS
NOTE: POSITIVE HYDRODYNAMIC MOMENTS TEND TO RAISE THE BOW.
MODEL NO. DESIGNATION
654 6-58-8
634 8-58-10.66
685 10-58-13.33
$K_{3/2}$ (CONSTANT) = 0.058
UPPER MOMENT STABILITY LIMITS
685
634
654
MODEL SPEED, FT./SEC.
HYDRODYNAMIC MOMENT, INCH LBS.
654
634
685
LOWER MOMENT STABILITY LIMITS

HYDRODYNAMIC CHARACTERISTICS OF THREE MODELS WITH DIFFERING FOREBODY LENGTH WITH CONSTANT PLANFORM AREA ($K_{3/2}$)	L/b	$\%L_f$	b	C_{Δ_0}	LINE SYMBOL
	6.00	55	5.49"	0.86	———
	6.00	58	5.49"	0.86	--------
	6.00	61	5.49"	0.86	—·—·



MODEL PARTICULARS

$\%L_f$	55	58	61
STERNPOST ANGLE	8.4°	8.5°	8.6°
$K_{3/2}$ (CONSTANT)	0.058	0.058	0.058
L	32.94"	32.94"	32.94"
L_f	18.12"	19.11"	20.04"

EXPERIMENTAL TOWING TANK
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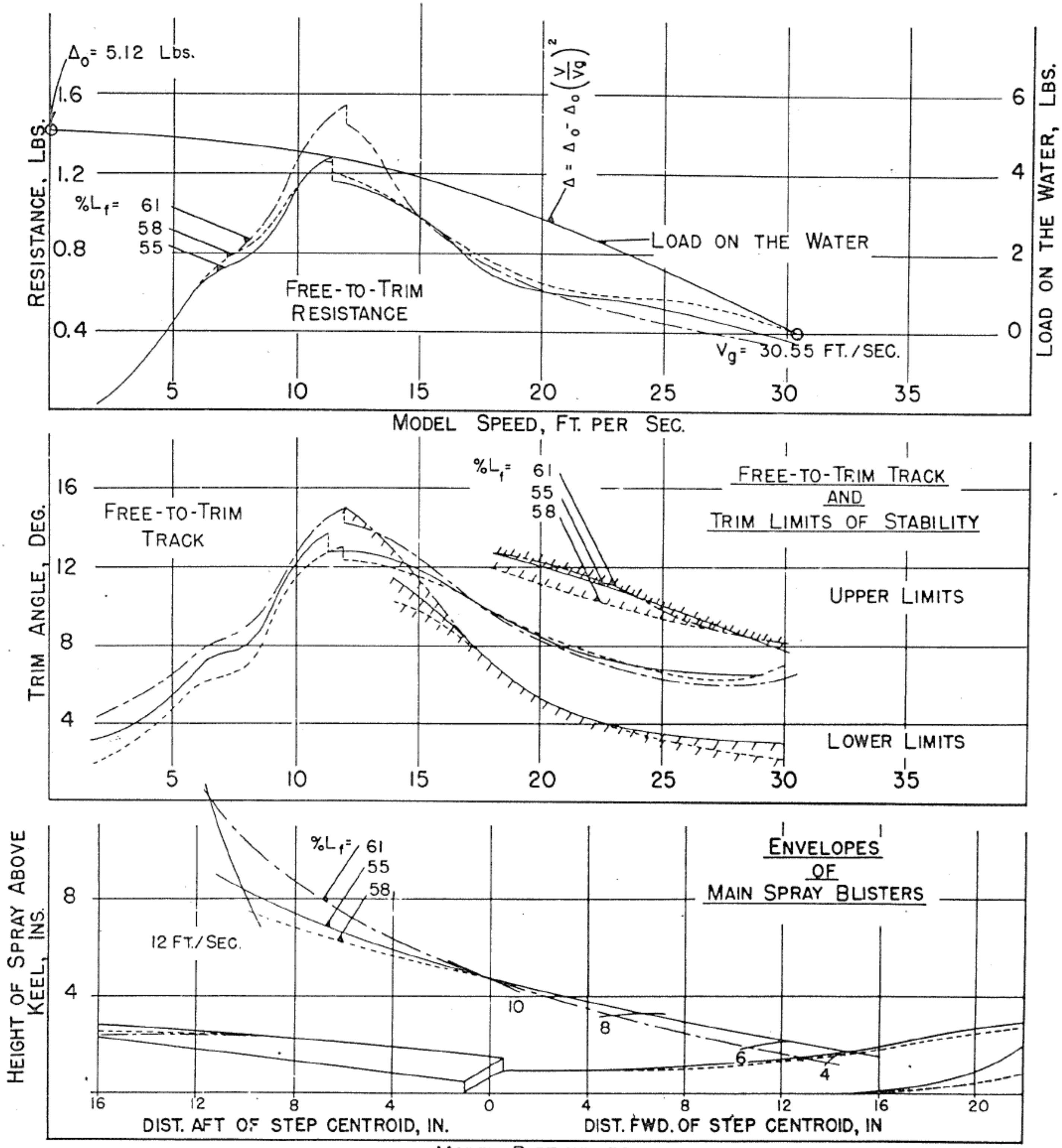
HYDRODYNAMIC CHARACTERISTICS OF THREE MODELS WITH DIFFERING FOREBODY LENGTH WITH CONSTANT PLANFORM AREA ($K_{3/2}$)	L/b	%L_f	b	C_{Δ_o}	LINE SYMBOL
	8.00	55	4.75"	1.33	———
	8.00	58	4.75"	1.33	-------
	8.00	61	4.75"	1.33	—-—

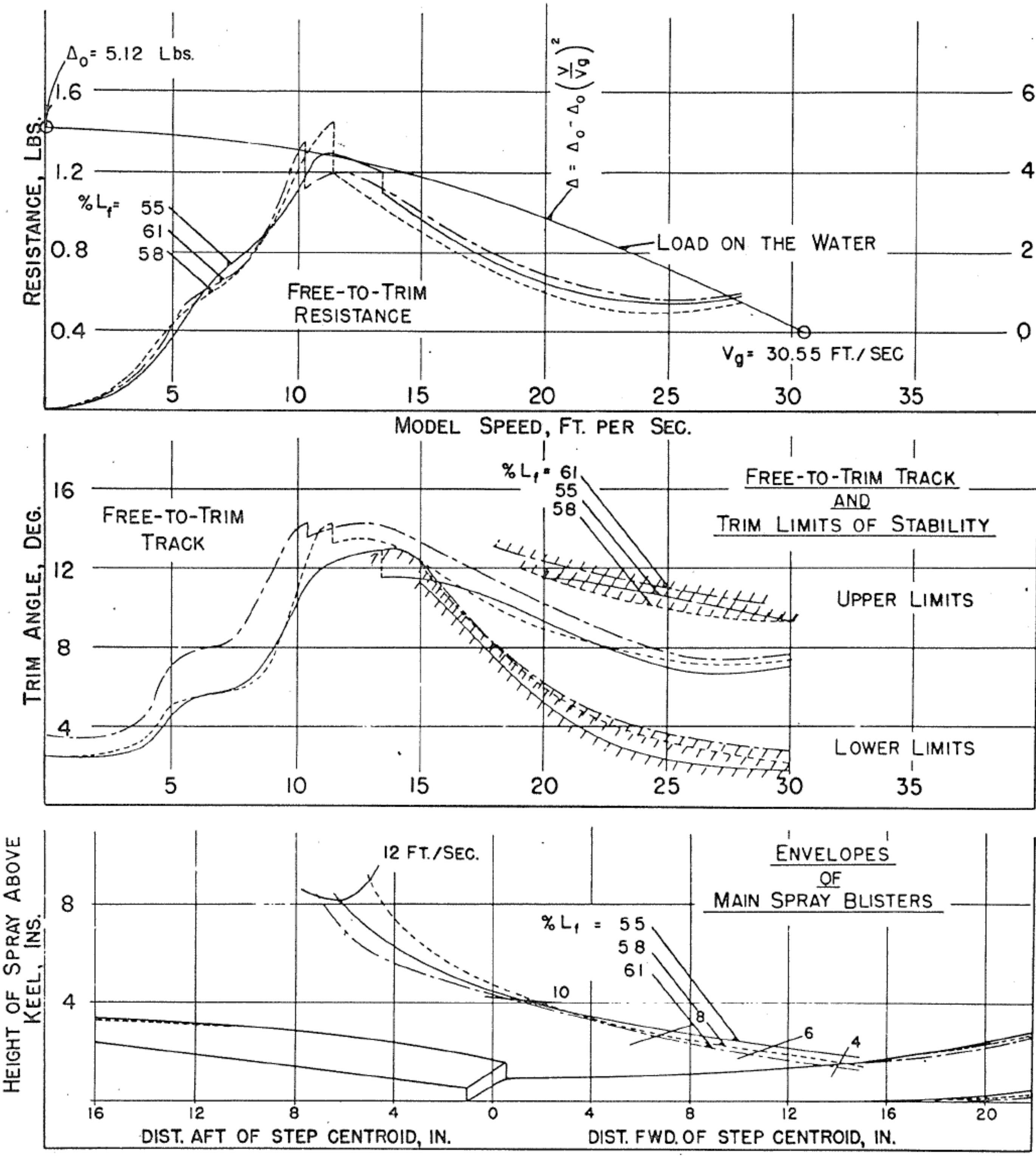


MODEL PARTICULARS

%L_f	55	58	61
STERNPOST ANGLE	8.3°	8.4°	8.5°
$K_{3/2}$ (CONSTANT)	0.058	0.058	0.058
L	38.00"	38.00"	38.00"
L_f	20.90"	22.04"	23.18"

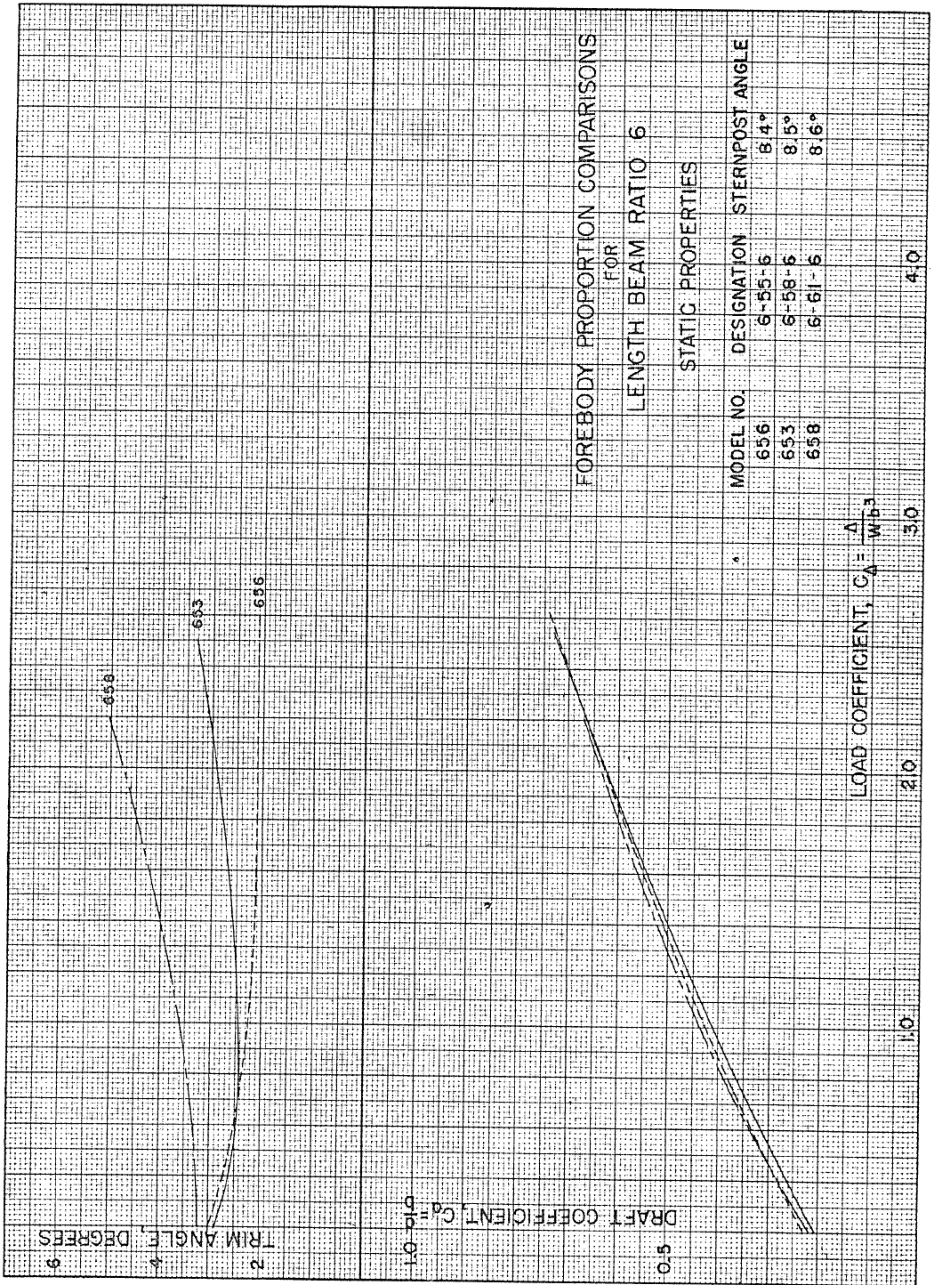
HYDRODYNAMIC CHARACTERISTICS OF THREE MODELS WITH DIFFERING FOREBODY LENGTH WITH CONSTANT PLANFORM AREA ($K_{3/2}$)

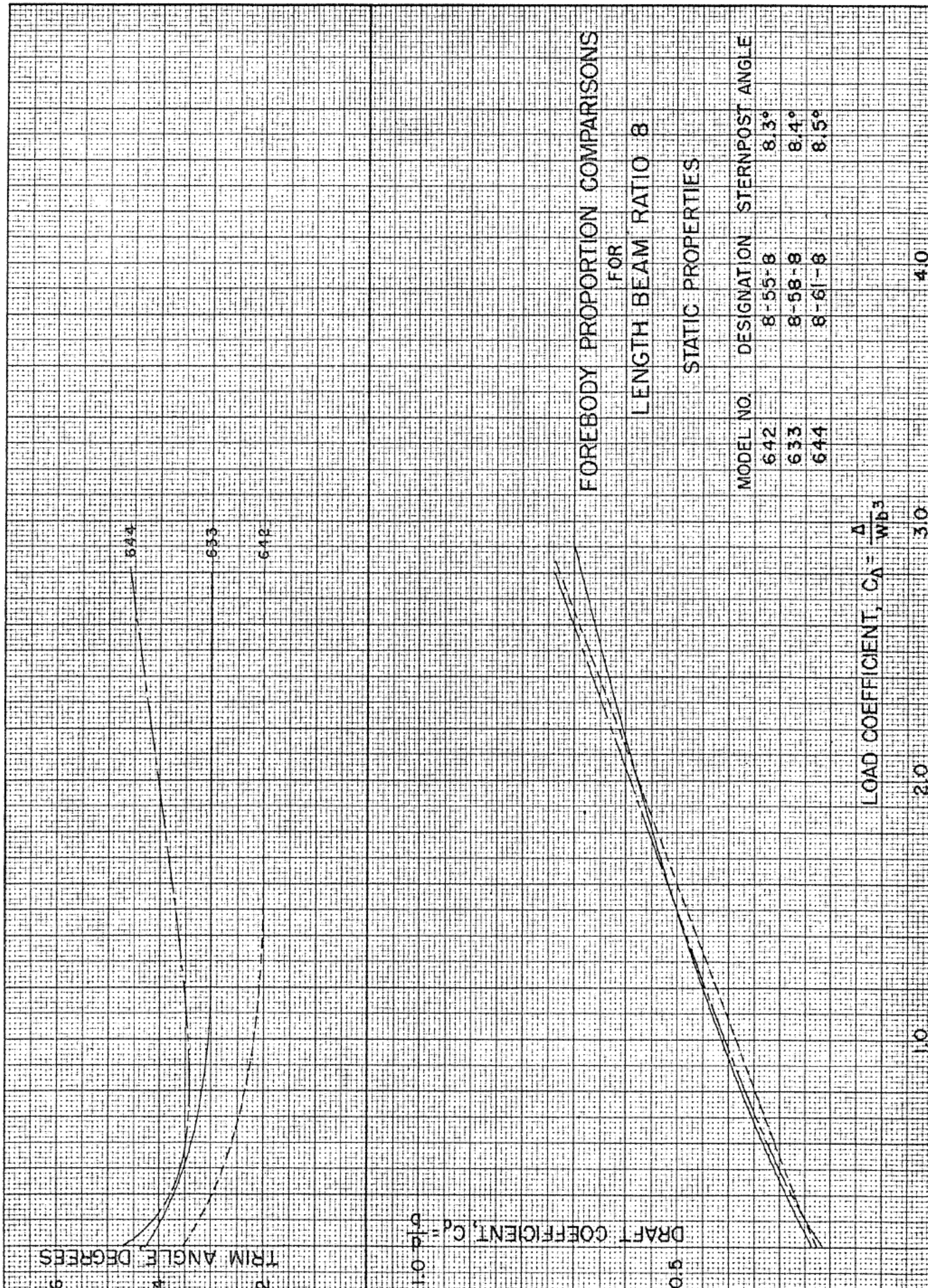
L/b	%L_f	b	C_{Δ_0}	LINE SYMBOL
10	55	4.25"	1.85	———
10	58	4.25"	1.85	-------
10	61	4.25"	1.85	—-—-

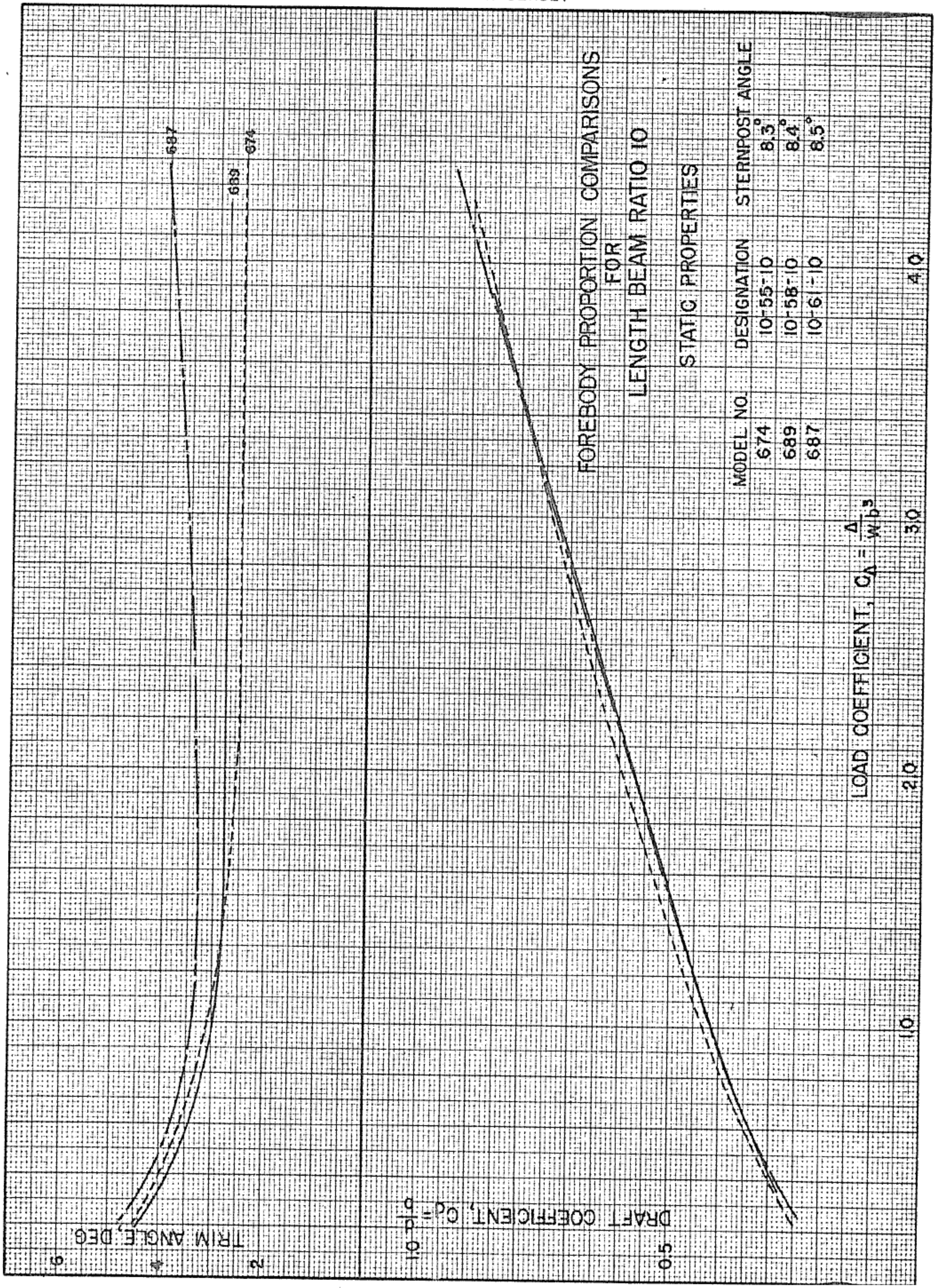


MODEL PARTICULARS

%L_f	55	58	61
STERNPOST ANGLE	8.3°	8.4°	8.5°
$K_{3/2}$ (CONSTANT)	0.058	0.058	0.058
L	42.50"	42.50"	42.50"
L_f	23.38"	24.65"	25.93"


FOREBODY PROPORTION COMPARISONS
FOR
LENGTH BEAM RATIO 6
STATIC PROPERTIES
MODEL NO. | DESIGNATION | STERNPOST ANGLE
656 | 6-55-6 | 8.4°
653 | 6-58-6 | 8.5°
658 | 6-61-6 | 8.6°
TRIM ANGLE, DEGREES
6
4
2
658
653
656
DRAFT COEFFICIENT, $C_d = \frac{d}{b}$
1.0
0.5
LOAD COEFFICIENT, $C_\Delta = \frac{\Delta}{wb^3}$
1.0
2.0
3.0
4.0


FOREBODY PROPORTION COMPARISONS
FOR
LENGTH BEAM RATIO 8
STATIC PROPERTIES
MODEL NO. DESIGNATION STERNPOST ANGLE
642 8-55-8 8.3°
633 8-58-8 8.4°
644 8-61-8 8.5°
644
633
642
TRIM ANGLE DEGREES
6
4
2
DRAFT COEFFICIENT, $C_d = \frac{d}{b}$
1.0
0.5
LOAD COEFFICIENT, $C_\Delta = \frac{\Delta}{wb^3}$
1.0
2.0
3.0
4.0


FOREBODY PROPORTION COMPARISONS
FOR
LENGTH BEAM RATIO 10
STATIC PROPERTIES
MODEL NO. DESIGNATION STERNPOST ANGLE
674 10-55-10 8.3°
689 10-58-10 8.4°
687 10-61-10 8.5°
687
689
674
LOAD COEFFICIENT, $C_\Delta = \frac{\Delta}{wb^3}$
1.0
2.0
3.0
4.0
DRAFT COEFFICIENT, $C_d = \frac{d}{b}$
1.0
0.5
TRIM ANGLE, DEG
6
4
2

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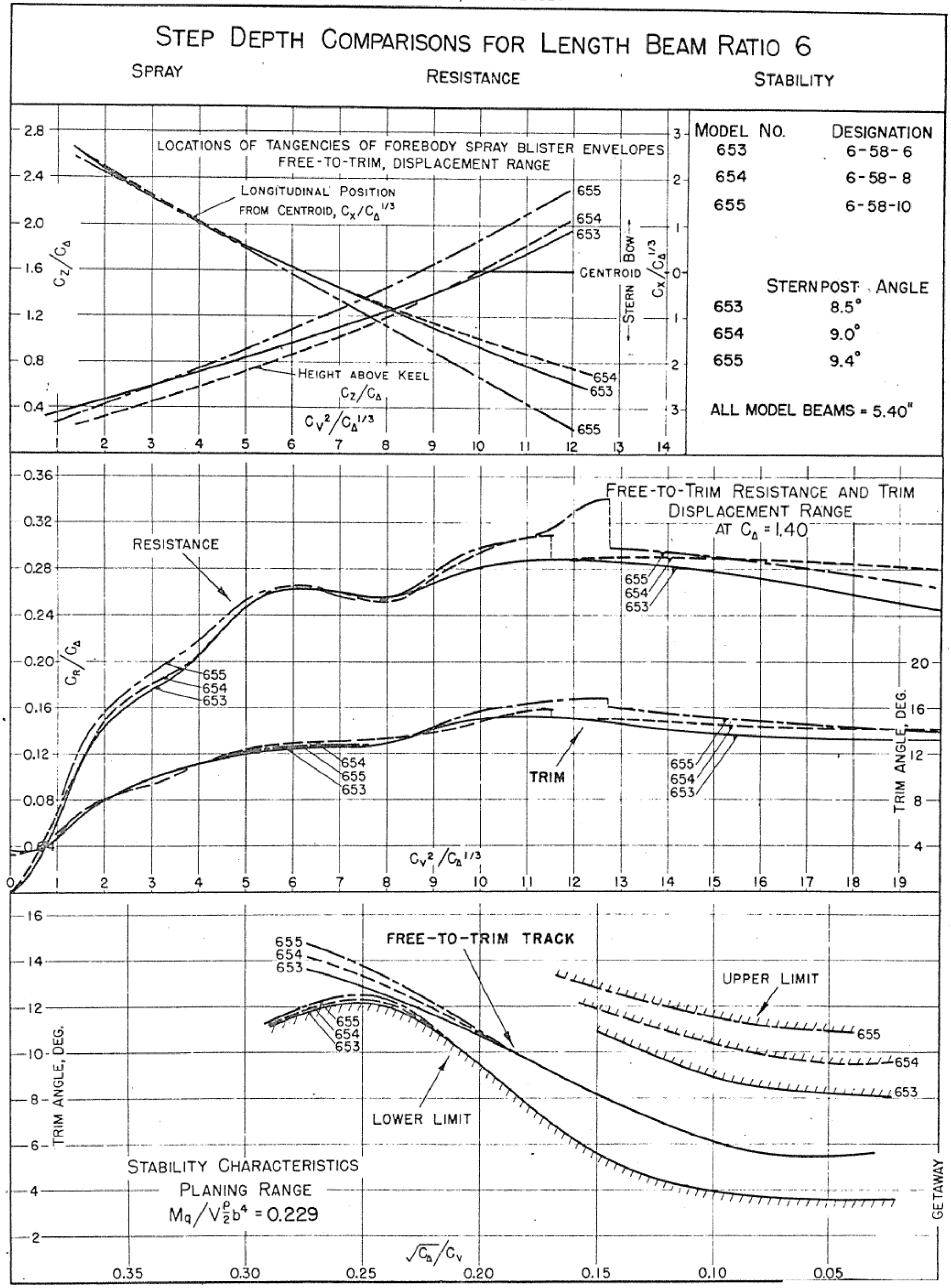
STEP DEPTH COMPARISONS FOR LENGTH BEAM RATIO 6



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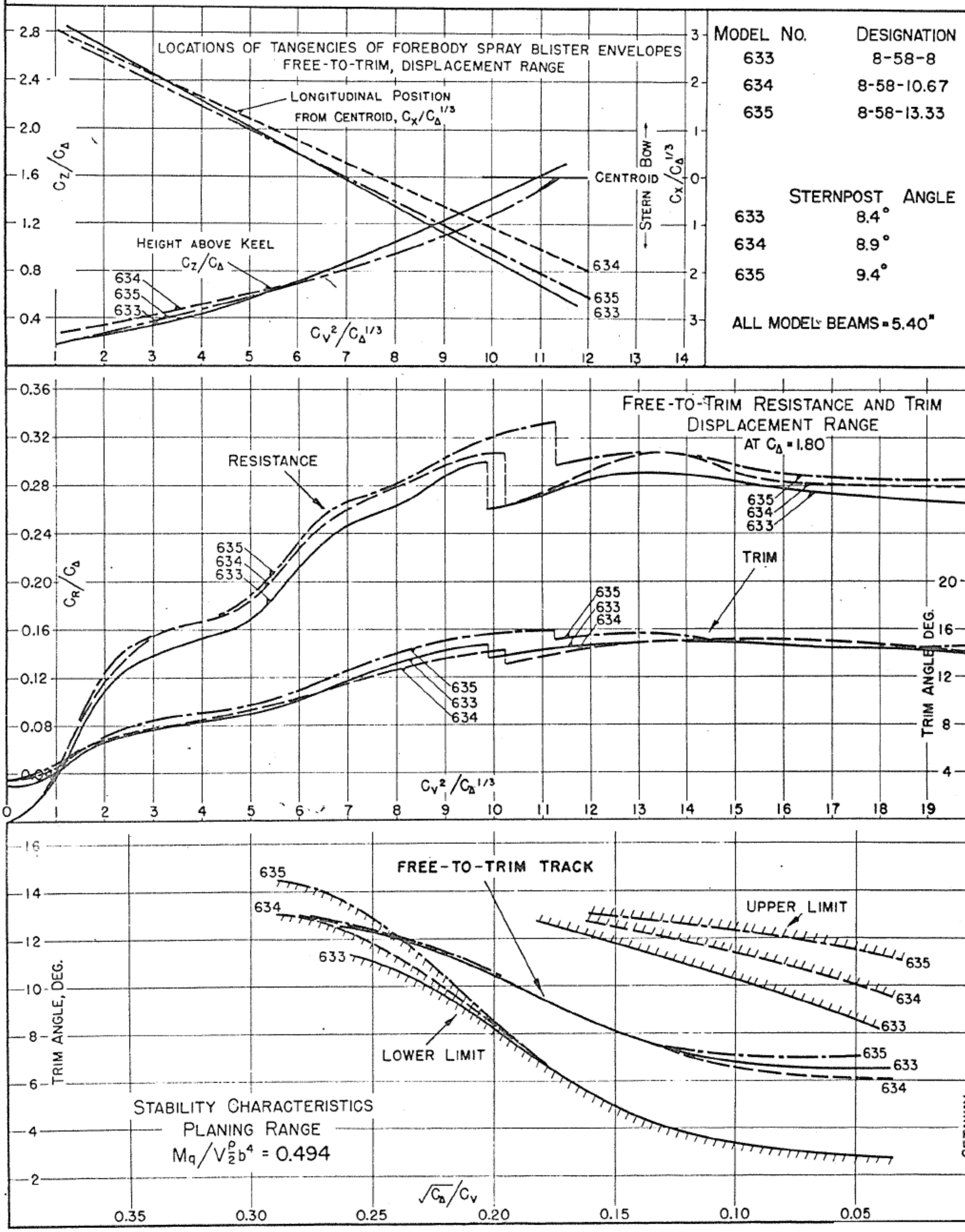
HOBOKEN, NEW JERSEY

STEP DEPTH COMPARISONS FOR LENGTH-BEAM RATIO 8

SPRAY RESISISTANCE STABILITY



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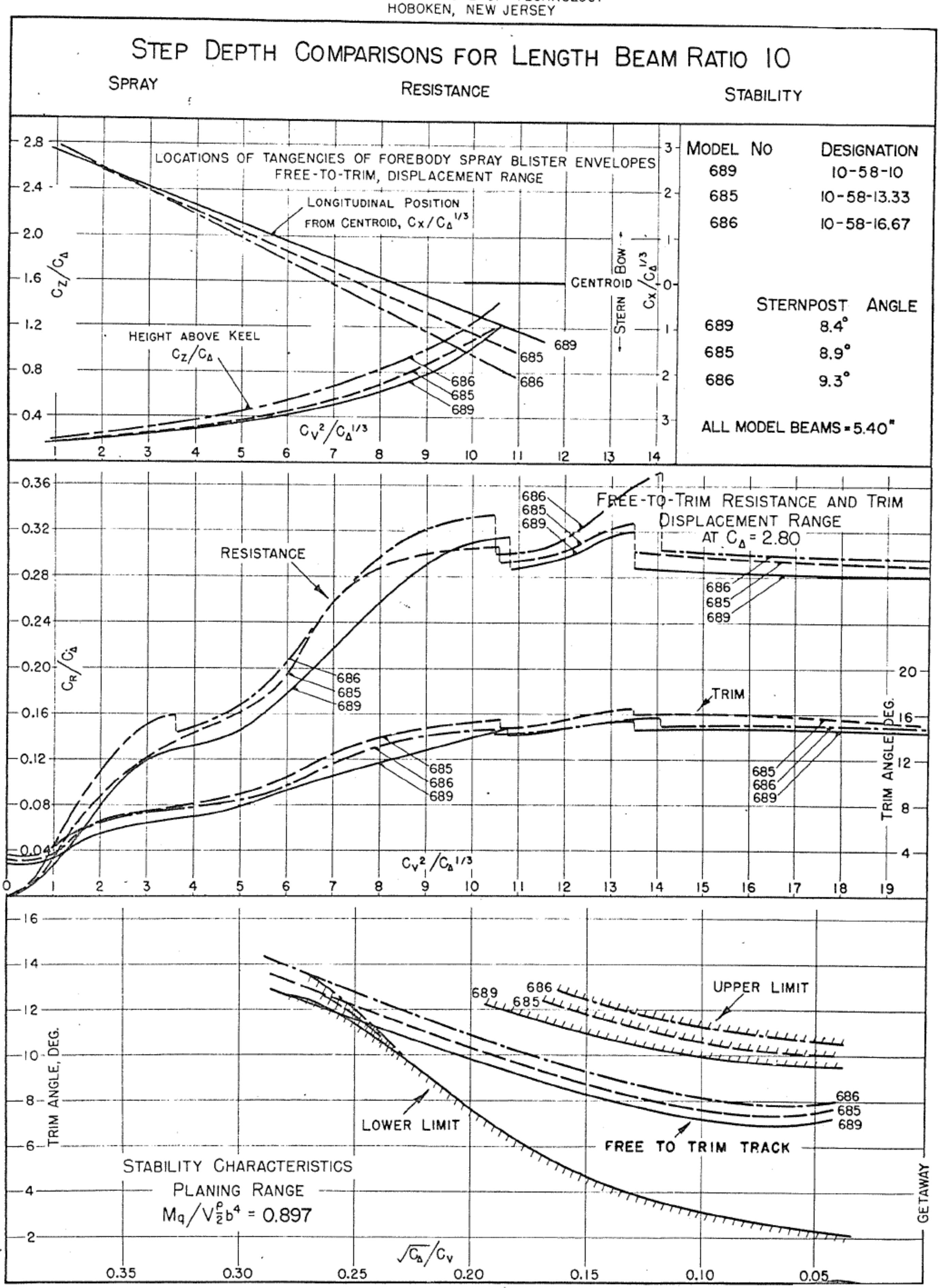

EXPERIMENTAL TOWING TANK
STEVENS INSTITUTE OF TECHNOLOGY
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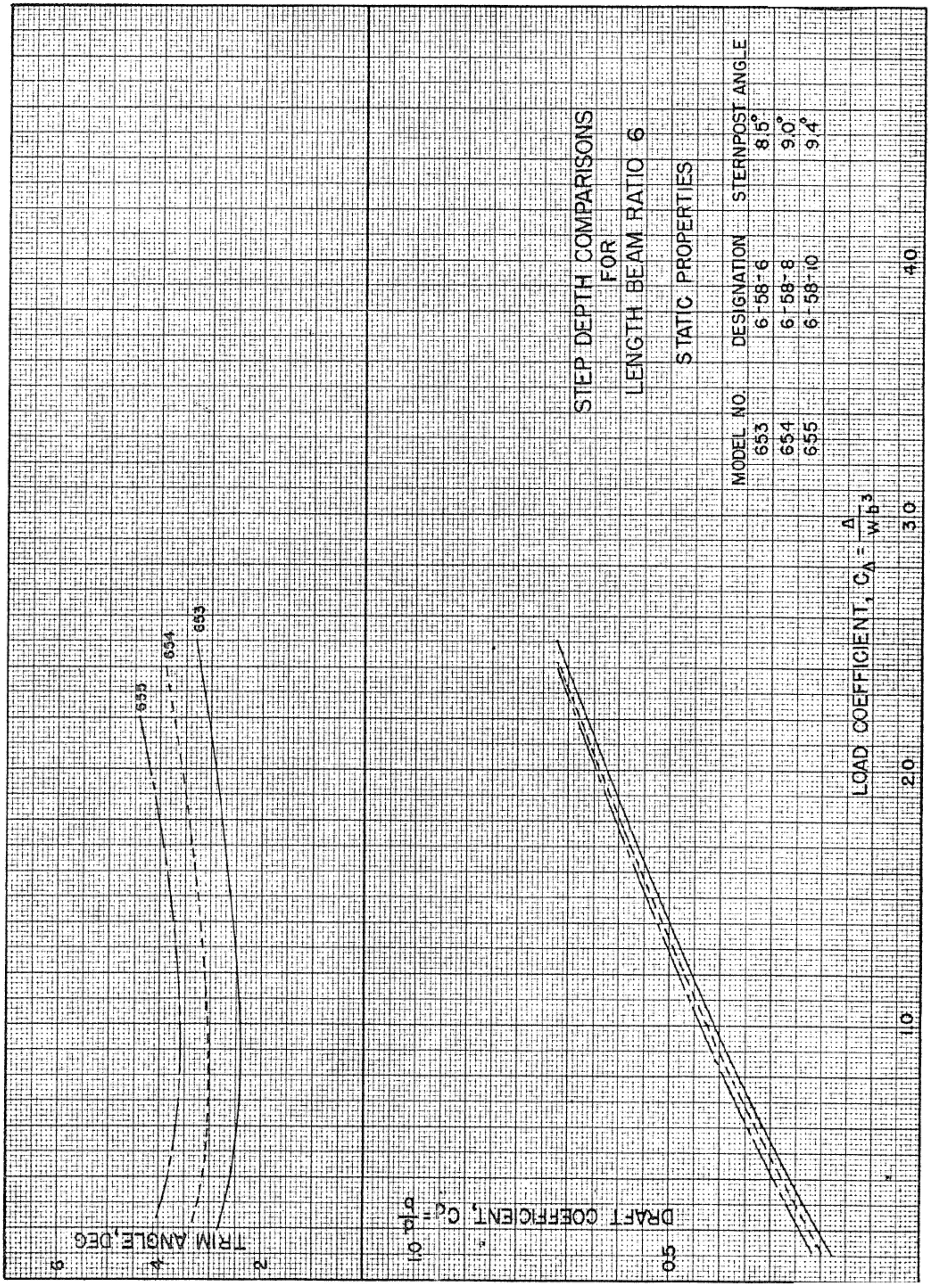

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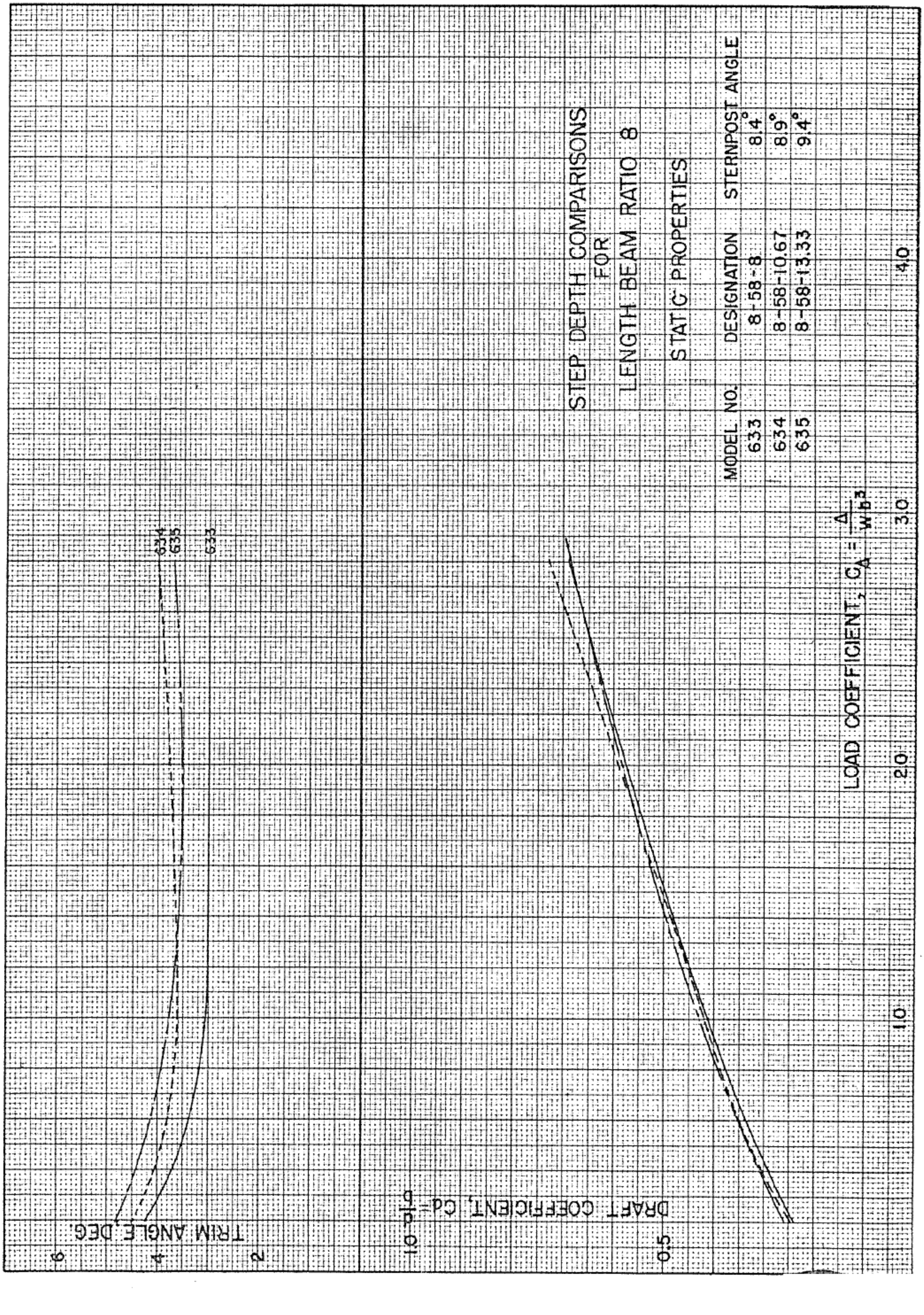
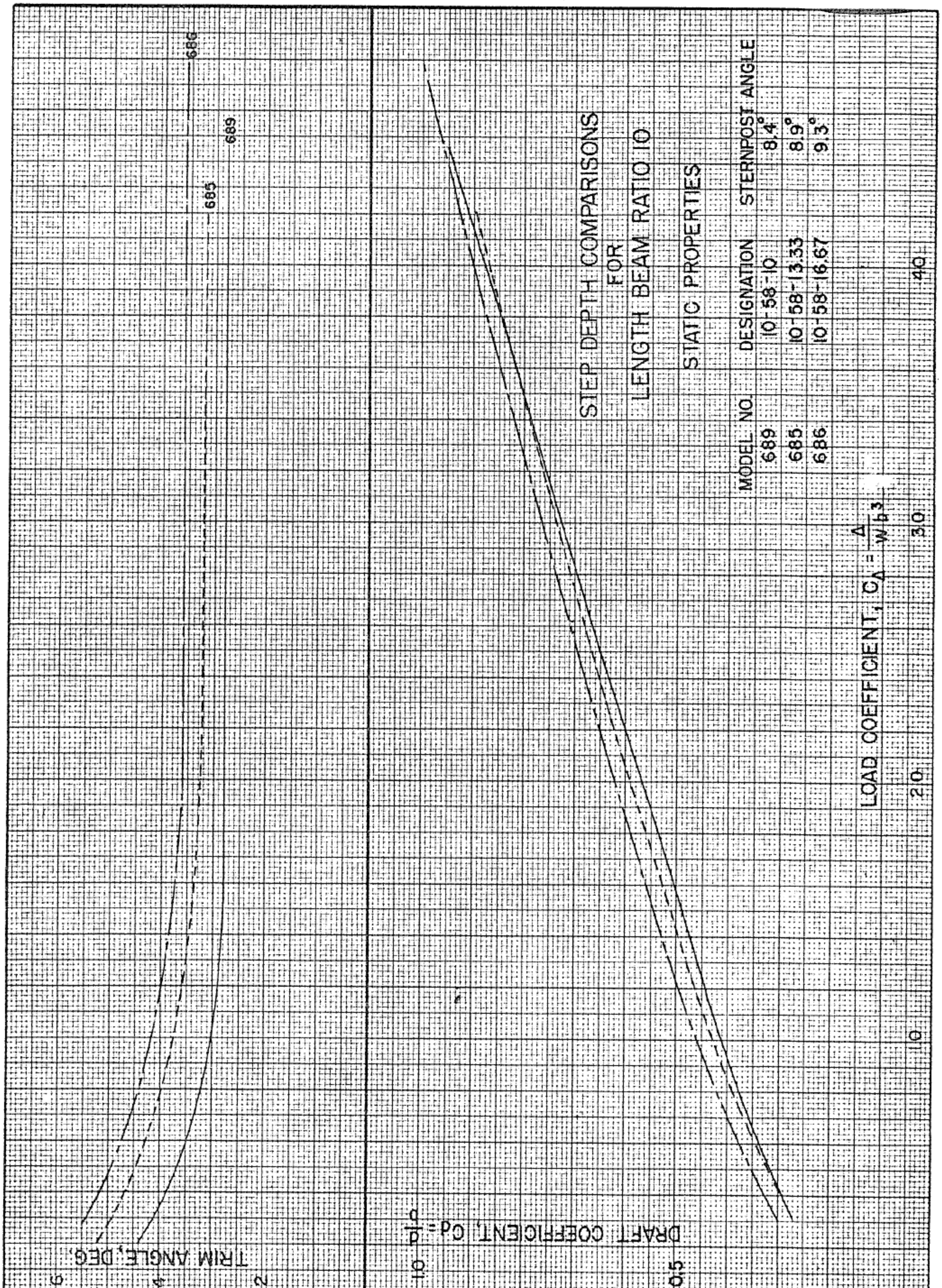
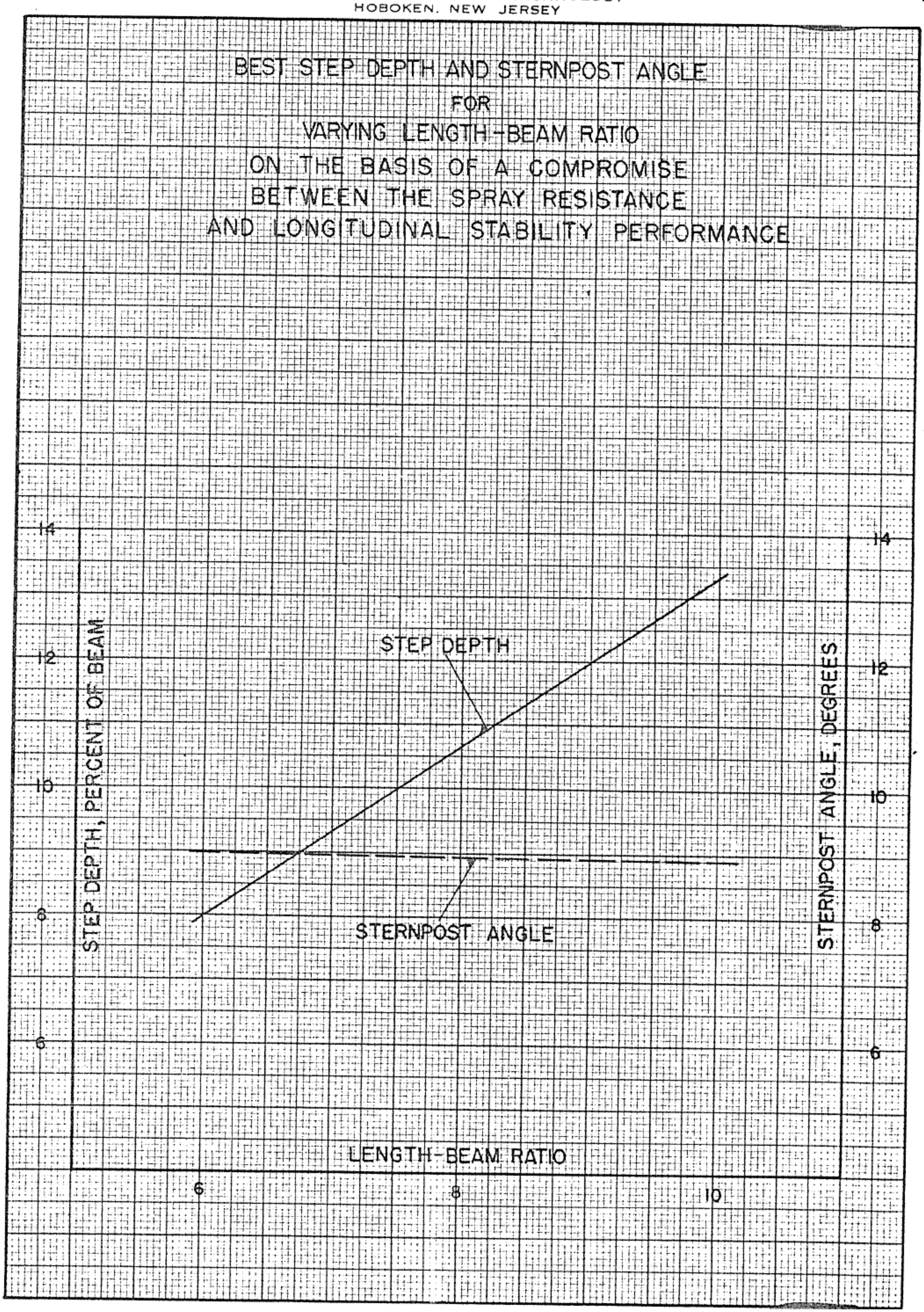



STEP DEPTH COMPARISONS
FOR
LENGTH BEAM RATIO 10
STATIC PROPERTIES
MODEL NO. DESIGNATION STERNPOST ANGLE
689 10-58-10 8.4°
685 10-58-13.33 8.9°
686 10-58-16.67 9.3°
686
689
685
TRIM ANGLE, DEG.
6
4
2
DRAFT COEFFICIENT, $C_d = \frac{d}{b}$
1.0
0.5
LOAD COEFFICIENT, $C_\Delta = \frac{\Delta}{w b^3}$
10
20
30
40


BEST STEP DEPTH AND STERNPOST ANGLE
FOR
VARYING LENGTH-BEAM RATIO
ON THE BASIS OF A COMPROMISE
BETWEEN THE SPRAY RESISTANCE
AND LONGITUDINAL STABILITY PERFORMANCE
STEP DEPTH, PERCENT OF BEAM
STERNPOST ANGLE, DEGREES
STEP DEPTH
STERNPOST ANGLE
LENGTH-BEAM RATIO
14
12
10
8
6
6
8
10

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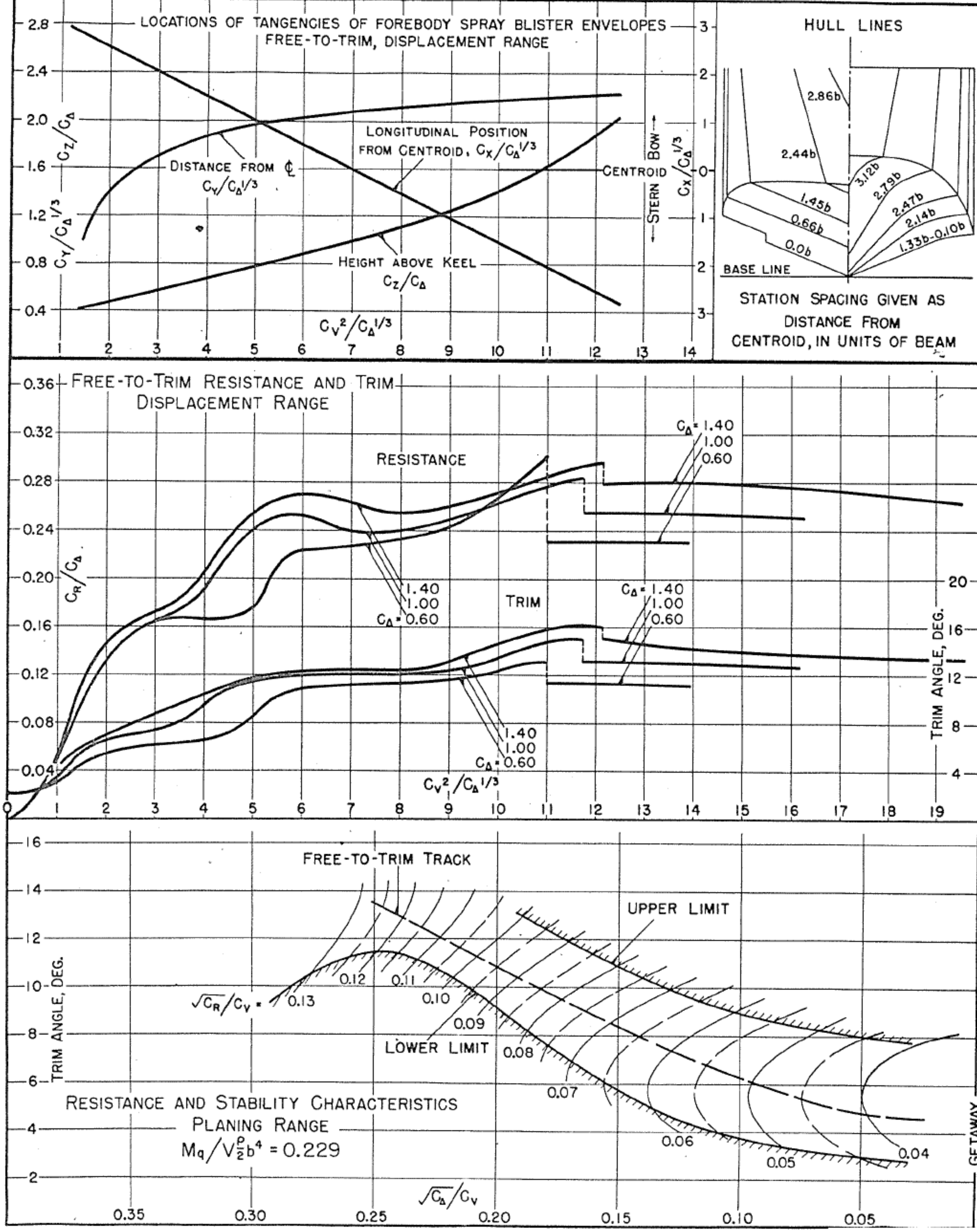
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: JUNE 13, 1945 C.G.= 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL C_{Δ_0} = 1.00 (NOMINAL) DESIGNATION: 6-55-6
MODEL BEAM: 5.40" k/L=0.234 MODEL NO. 656



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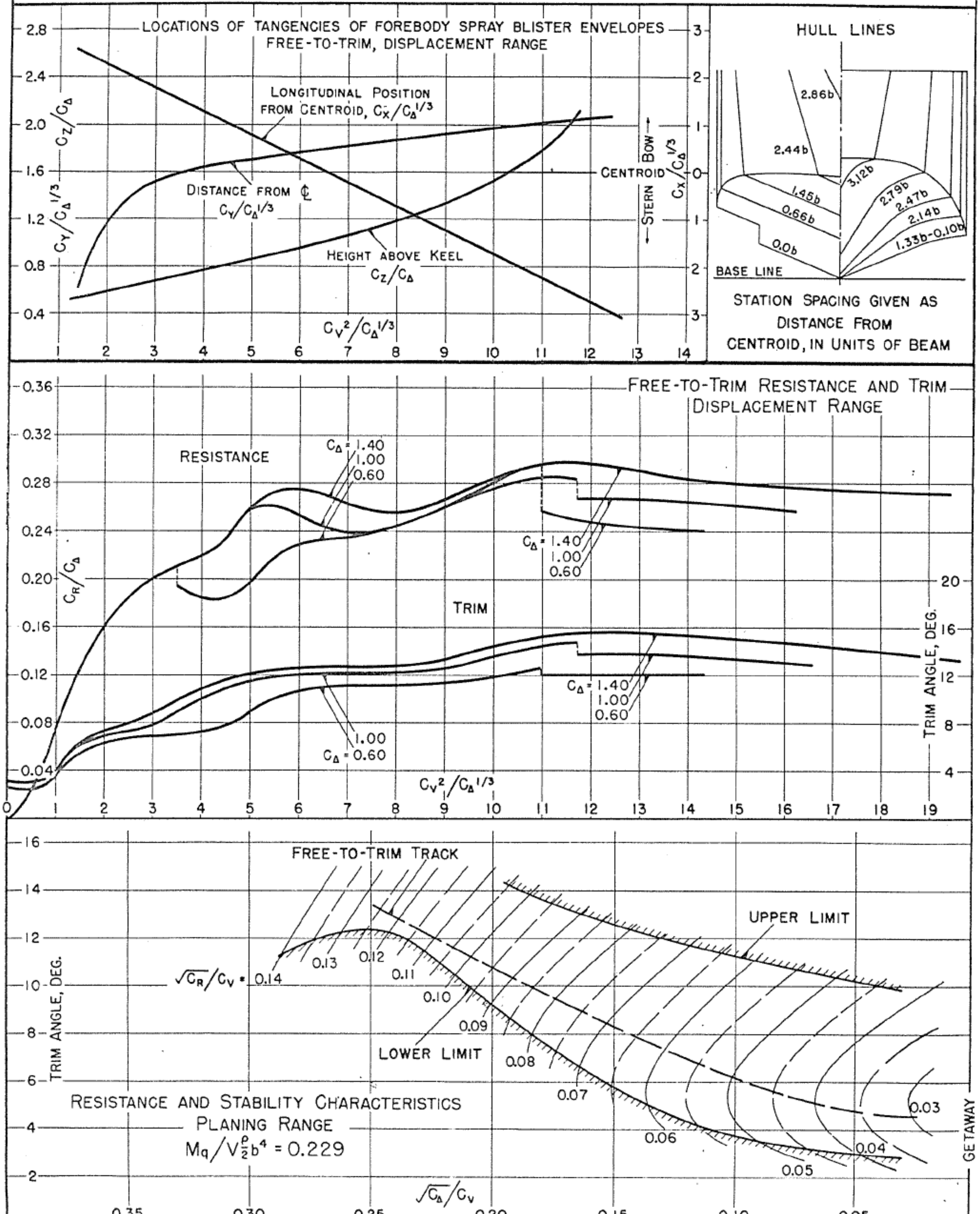
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: MAY 9, 1945 | C.G.= 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL | C_{Δ_0} = 1.00 (NOMINAL) | DESIGNATION: 6-55-10
MODEL BEAM: 5.40" | k/L = 0.234 | MODEL NO. 657



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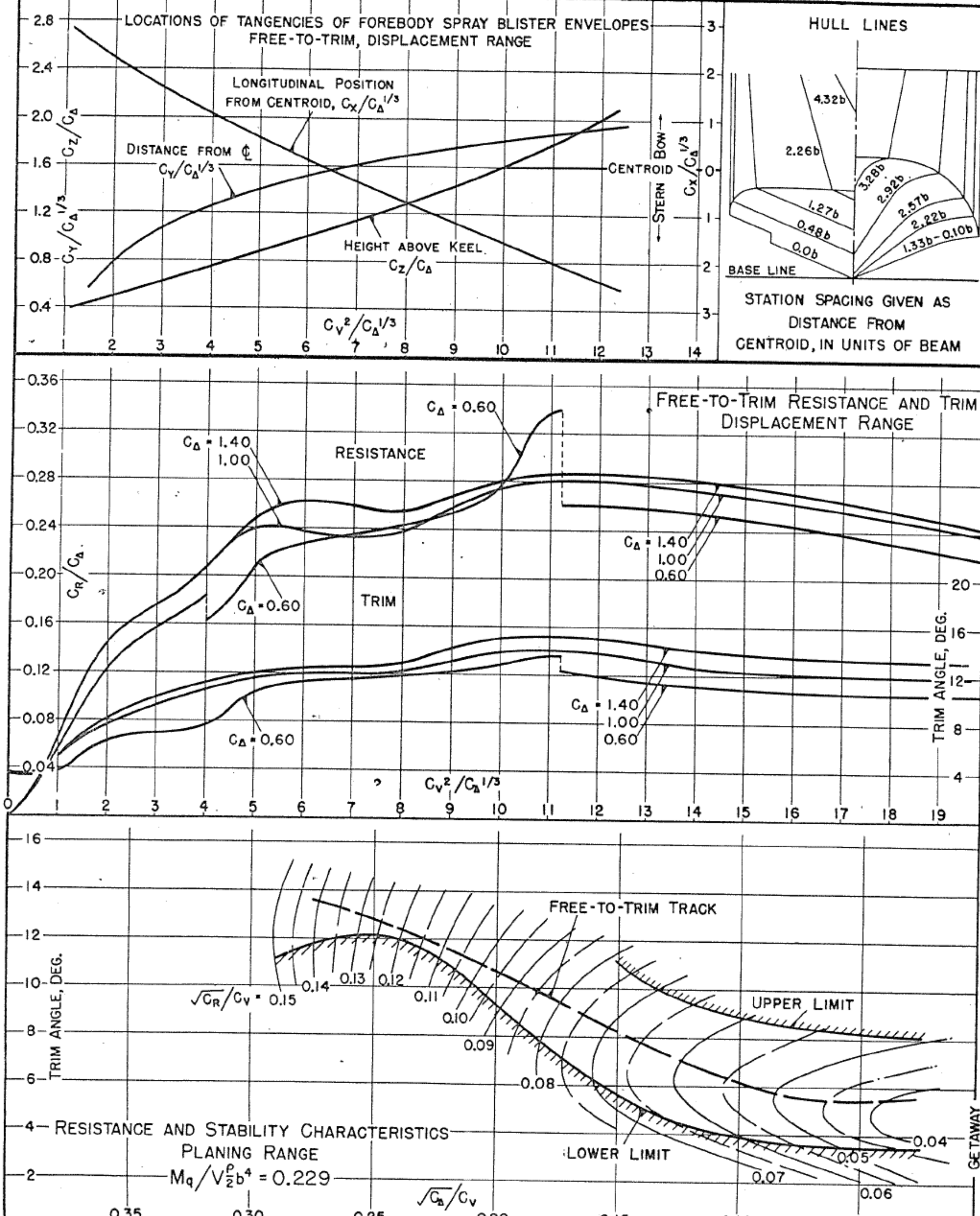
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: AUG. 21, 1945
MODEL BEAM: 5.40"
C.G.= 0.35 b FWD. OF CENTROID
0.90 b ABOVE KEEL
C_{Δ_0} = 1.00 (NOMINAL)
k/L = 0.234
DESIGNATION: 6-58-6
MODEL NO. 653



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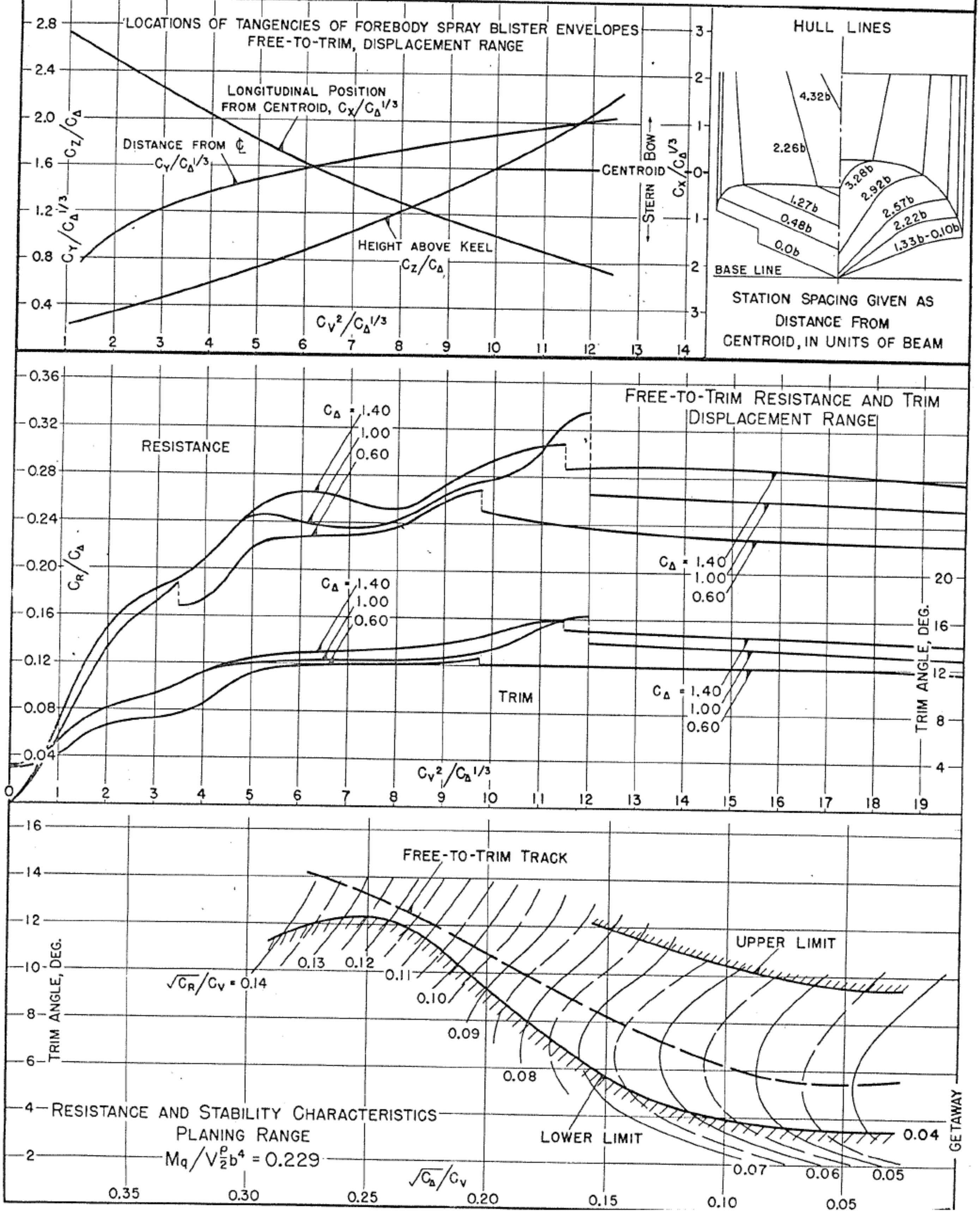
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: AUG. 24, 1945
MODEL BEAM: 5.40"
C.G.= 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL
C_{Δ_0} = 1.00 (NOMINAL)
k/L = 0.234
DESIGNATION: 6-58-8
MODEL NO. 654



N - 2
-49-
R-31
-70-

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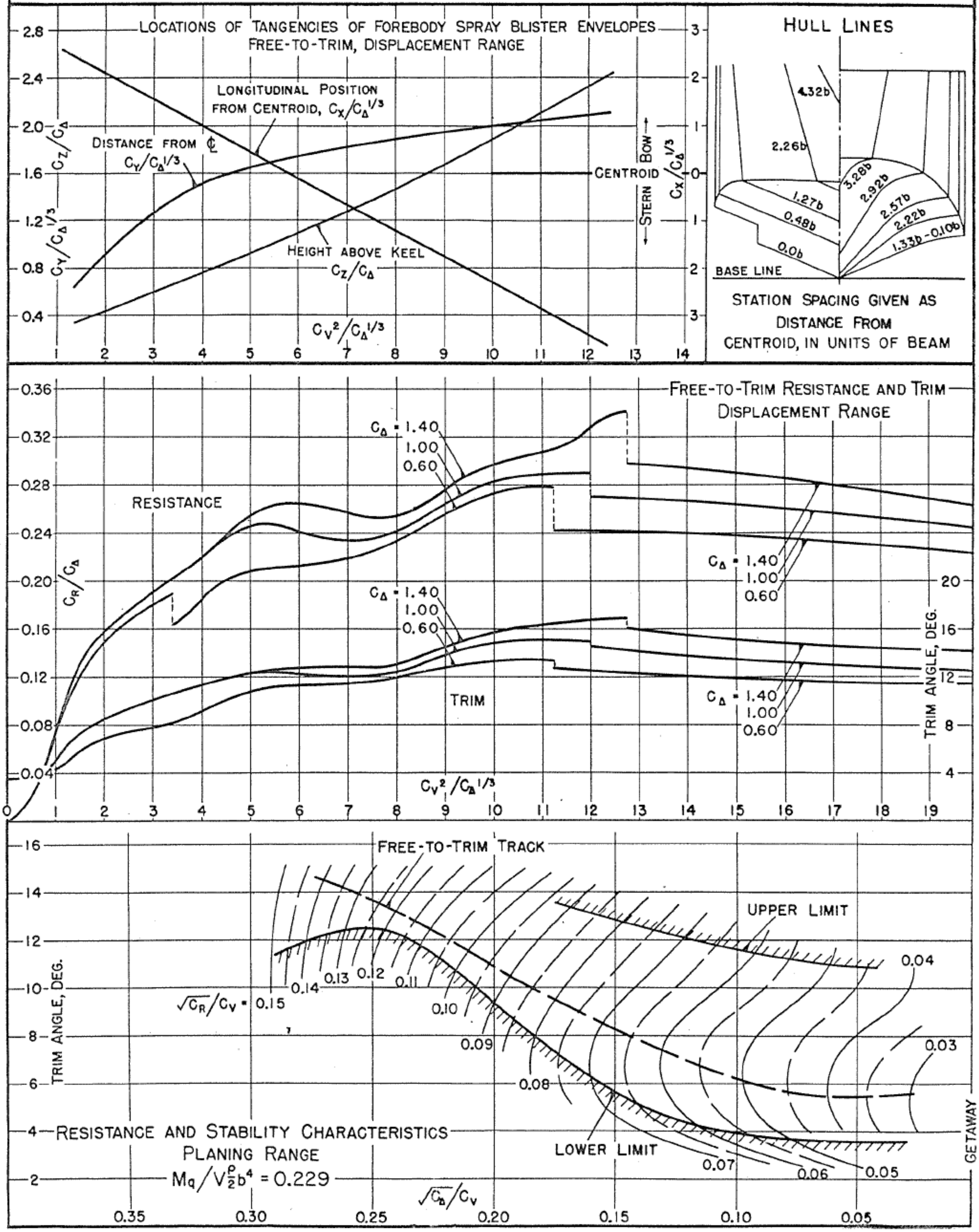
HOBOKEN, NEW JERSEY

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: SEPT. 1, 1945
MODEL BEAM: 5.40"
C.G.= 0.35b FWD. OF CENTROID, 0.90b ABOVE KEEL
C_{Δ_0} = 1.00 (NOMINAL)
k/L = 0.234
DESIGNATION: 6-58-10
MODEL NO. 655



N - 2
- 52 -
R - 31
- 71 -

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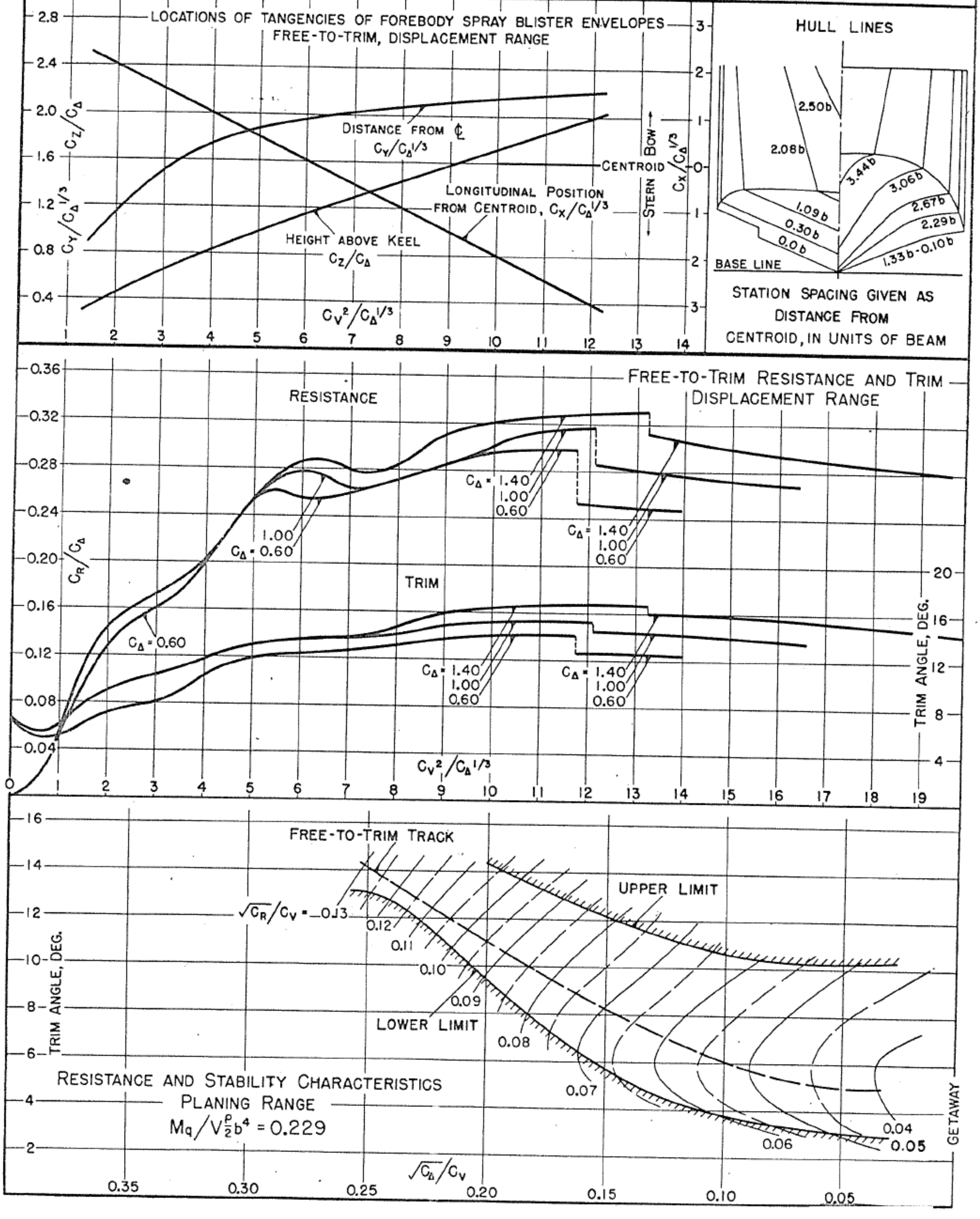
HOBOKEN, NEW JERSEY

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: JUNE 28, 1945 C.G.= 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL C_{Δ_0} = 1.00 (NOMINAL) DESIGNATION: 6-61-6
MODEL BEAM: 5.40" k/L = 0.234 MODEL NO. 658



N - 24
- 53 -
R - 31
- 72 -

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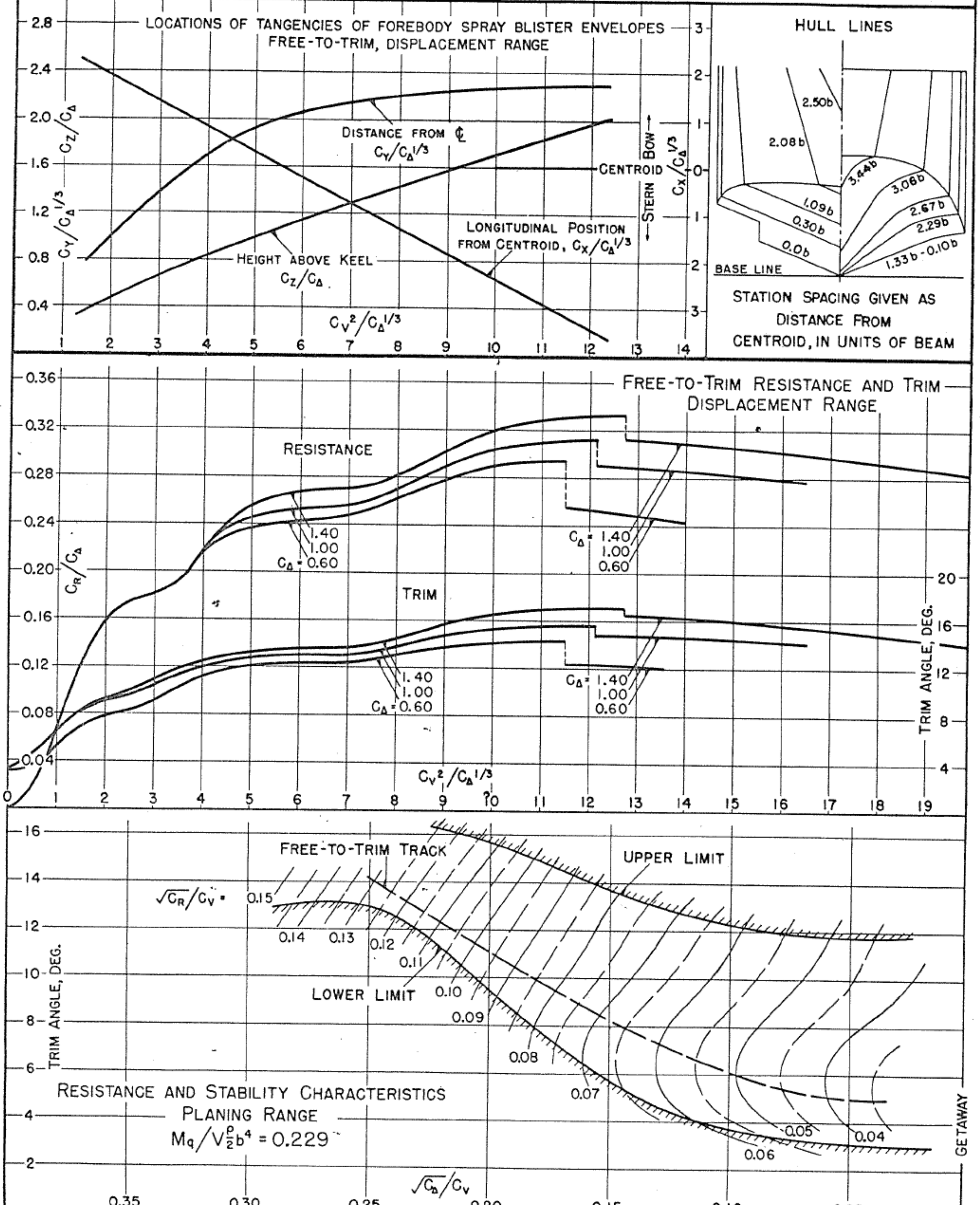
HOBOKEN, NEW JERSEY

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: JUNE 28, 1945 | C.G. = 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL | C_{Δ_0} = 1.00 (NOMINAL) | DESIGNATION: 6-61-10
MODEL BEAM: 5.40" | k/L = 0.234 | MODEL NO. 659



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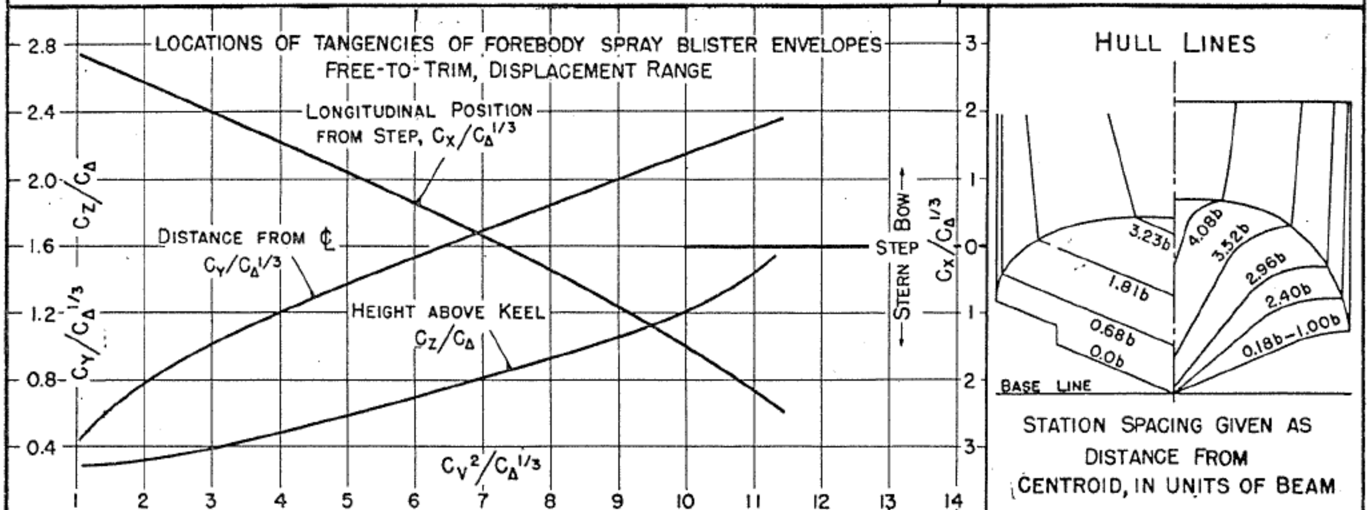
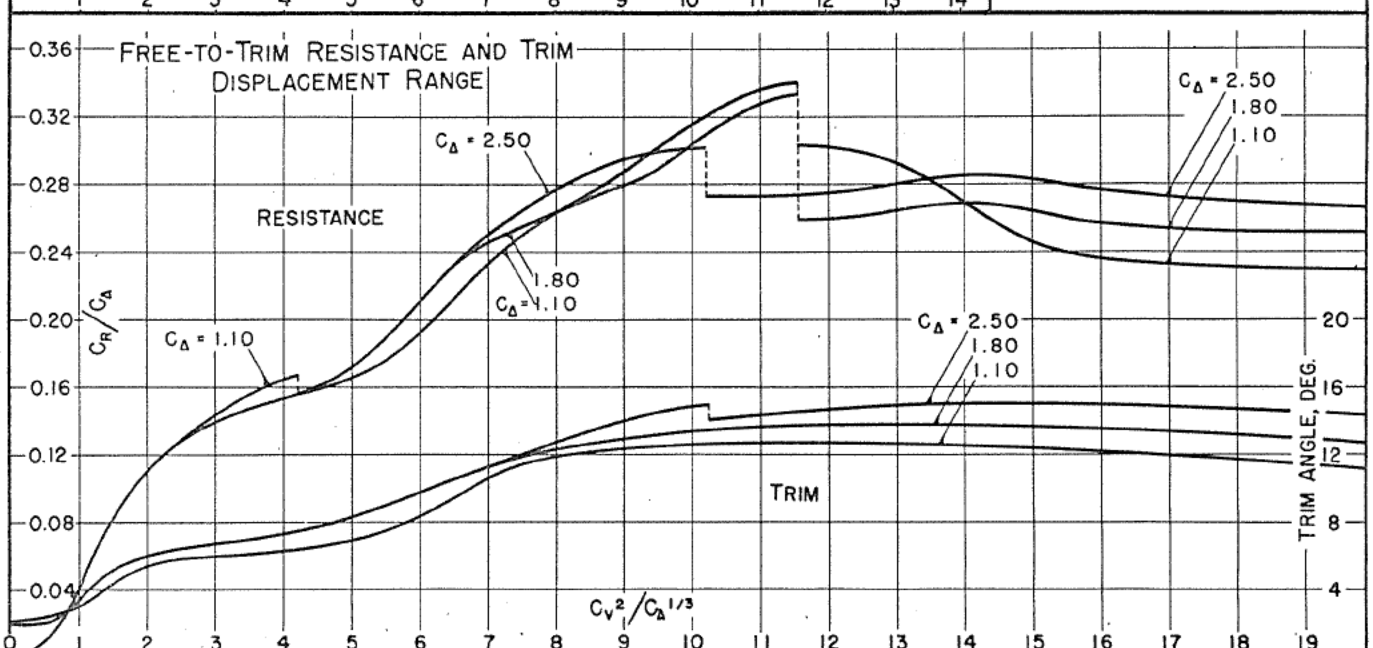
HOBOKEN, NEW JERSEY

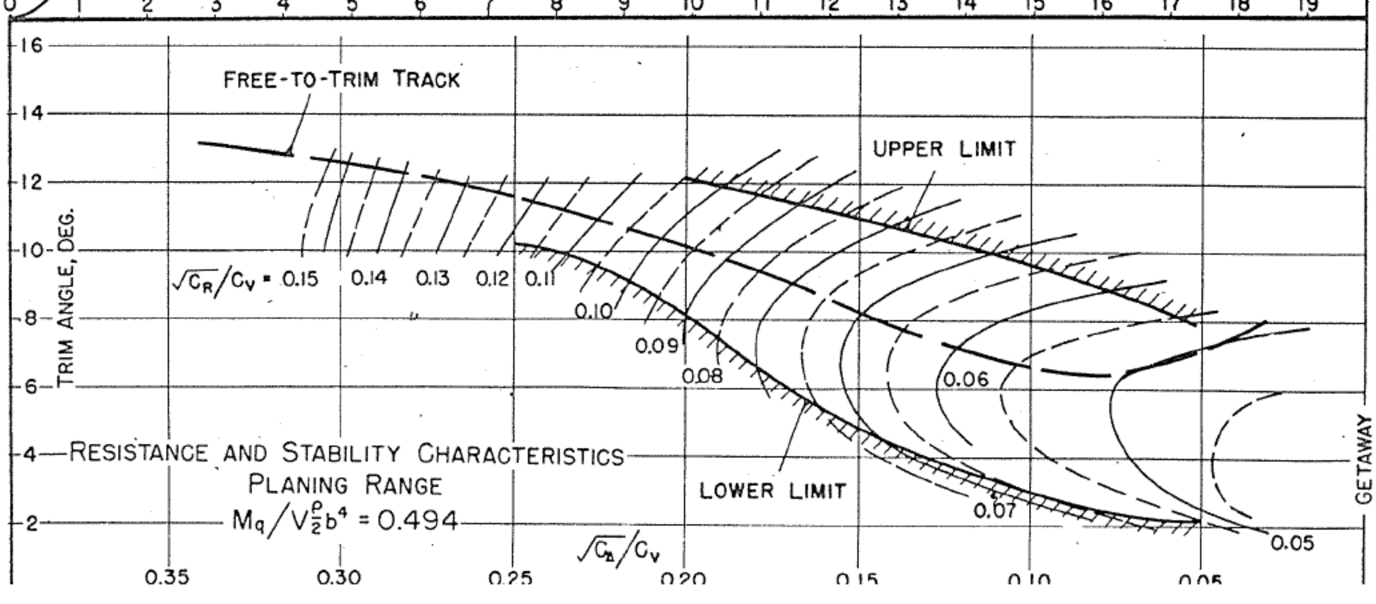
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: DEC. 12, 1945 (REVISED) APRIL 19, 1945 — C.G.= 0.35b FWD. OF CENTROID, 0.90b ABOVE KEEL — C_{Δ_0} = 1.80 (NOMINAL) — DESIGNATION: 8-55-8

MODEL BEAM: 5.40" — k/L=0.220 — MODEL NO. 642







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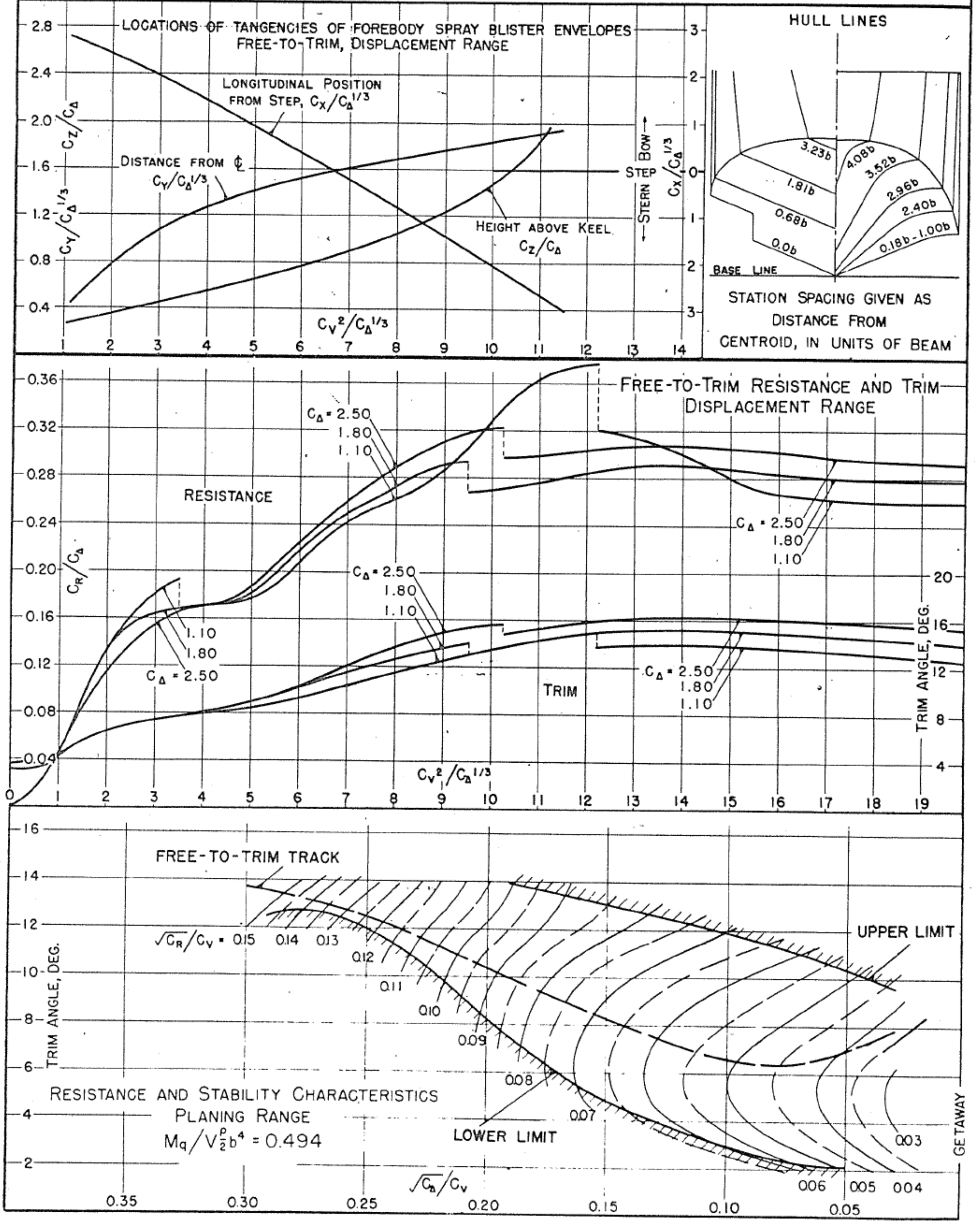
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: DEC. 12, 1945 (REVISED) APRIL 19, 1945
MODEL BEAM: 5.4"
C.G. = 0.35b FWD. OF CENTROID, 0.90b ABOVE KEEL
C_{Δ_0} = 1.80 (NOMINAL)
k/L = 0.220
DESIGNATION: 8-55-13.33
MODEL NO. 643



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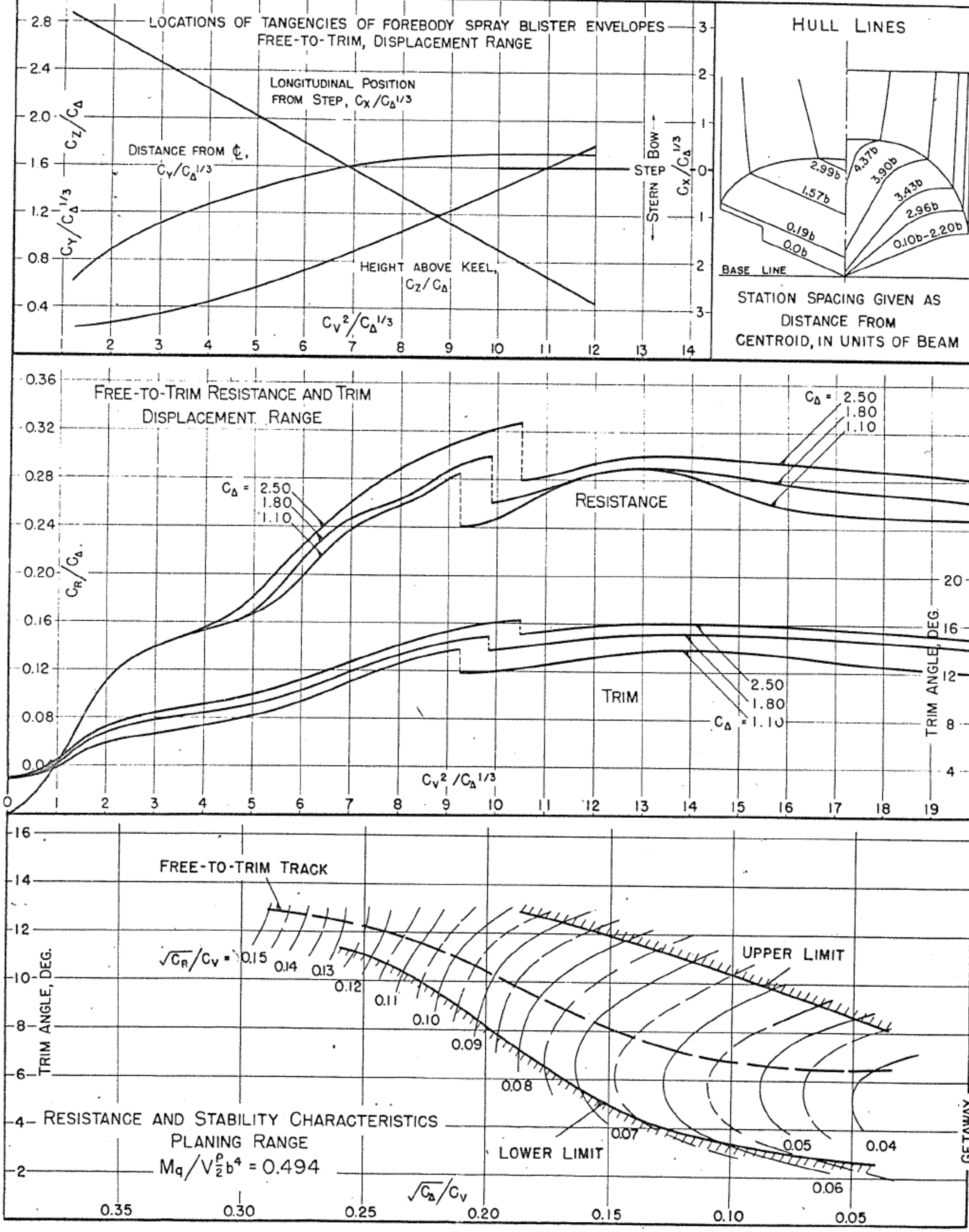
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: ~~JAN. 25, 1945~~ DEC. 12, 1945 (REVISED)
MODEL BEAM: 5.40"
C.G. = 0.35b FWD. OF CENTROID; 0.90b ABOVE KEEL
C_{Δ_0} = 1.80 (NOMINAL)
k/L = 0.220
DESIGNATION: 8-58-8
MODEL NO. 633-02



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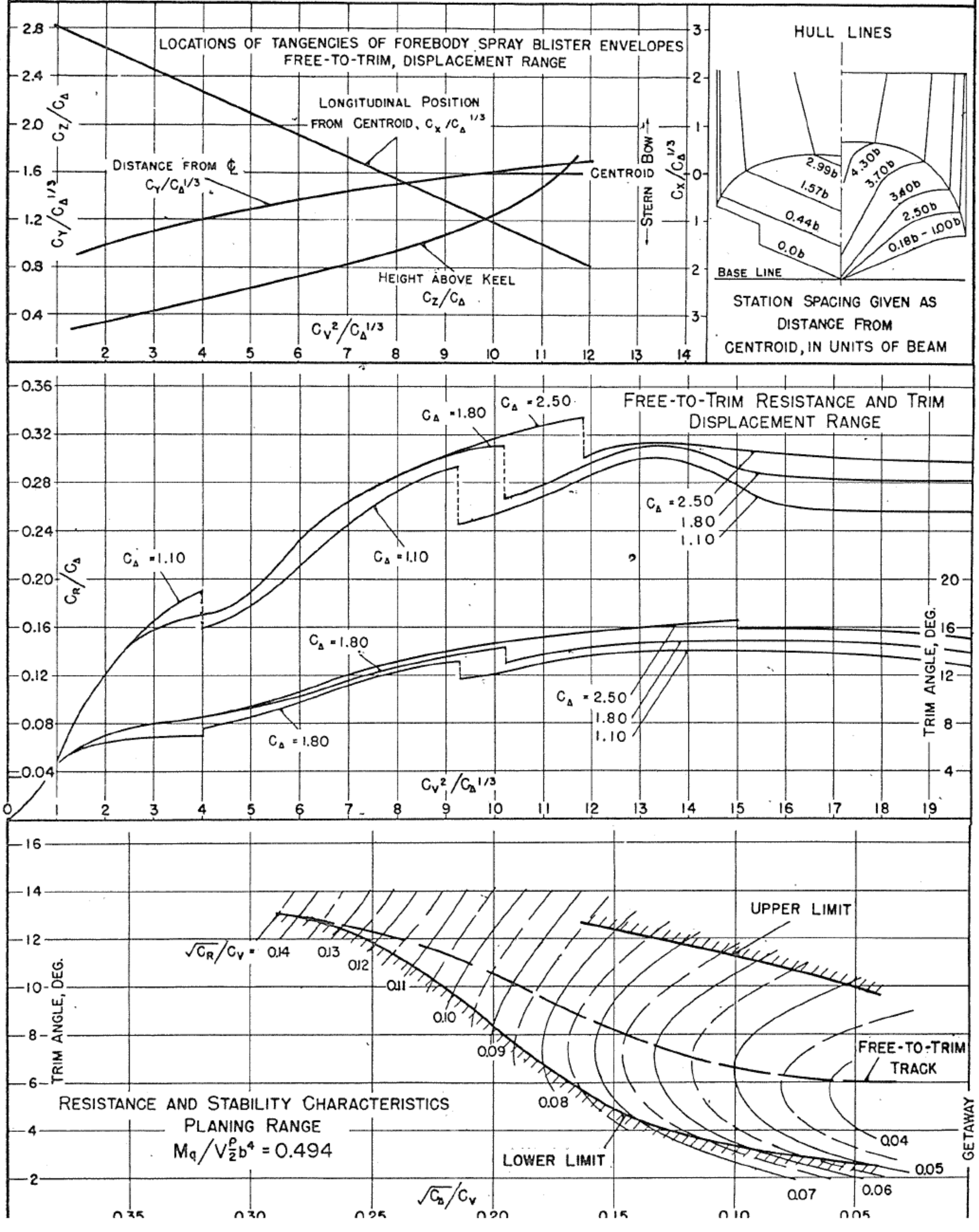
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: FEB. 28, 1946	C.G. = 0.35 b FWD. OF CENTROID; 0.90 b ABOVE KEEL	C_{Δ_0} = 1.80 (NOMINAL); k/L = 0.220	DESIGNATION: 8-58-10.66
MODEL BEAM: 5.40			MODEL NO. 634-03



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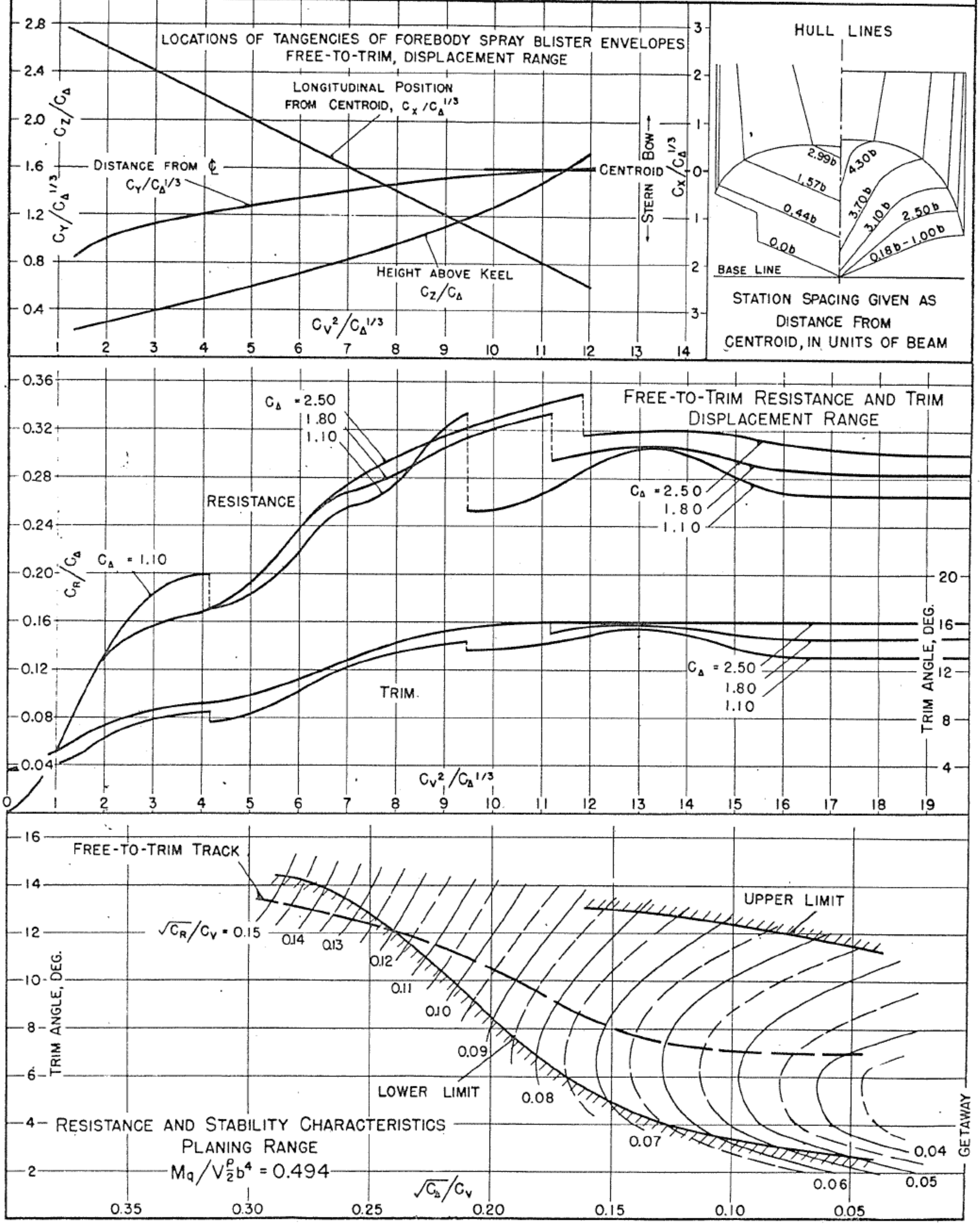
HOBOKEN, NEW JERSEY

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: MAR. 27, 1946
MODEL BEAM: 5.40
C.G. = 0.35b FWD. OF CENTROID, 0.90b ABOVE KEEL
$C_{\Delta_0} = 1.80$ (NOMINAL)
$k/L = 0.220$
DESIGNATION: 8-58-13.33
MODEL NO. 635-02



R-3l
-78
N-2
-28

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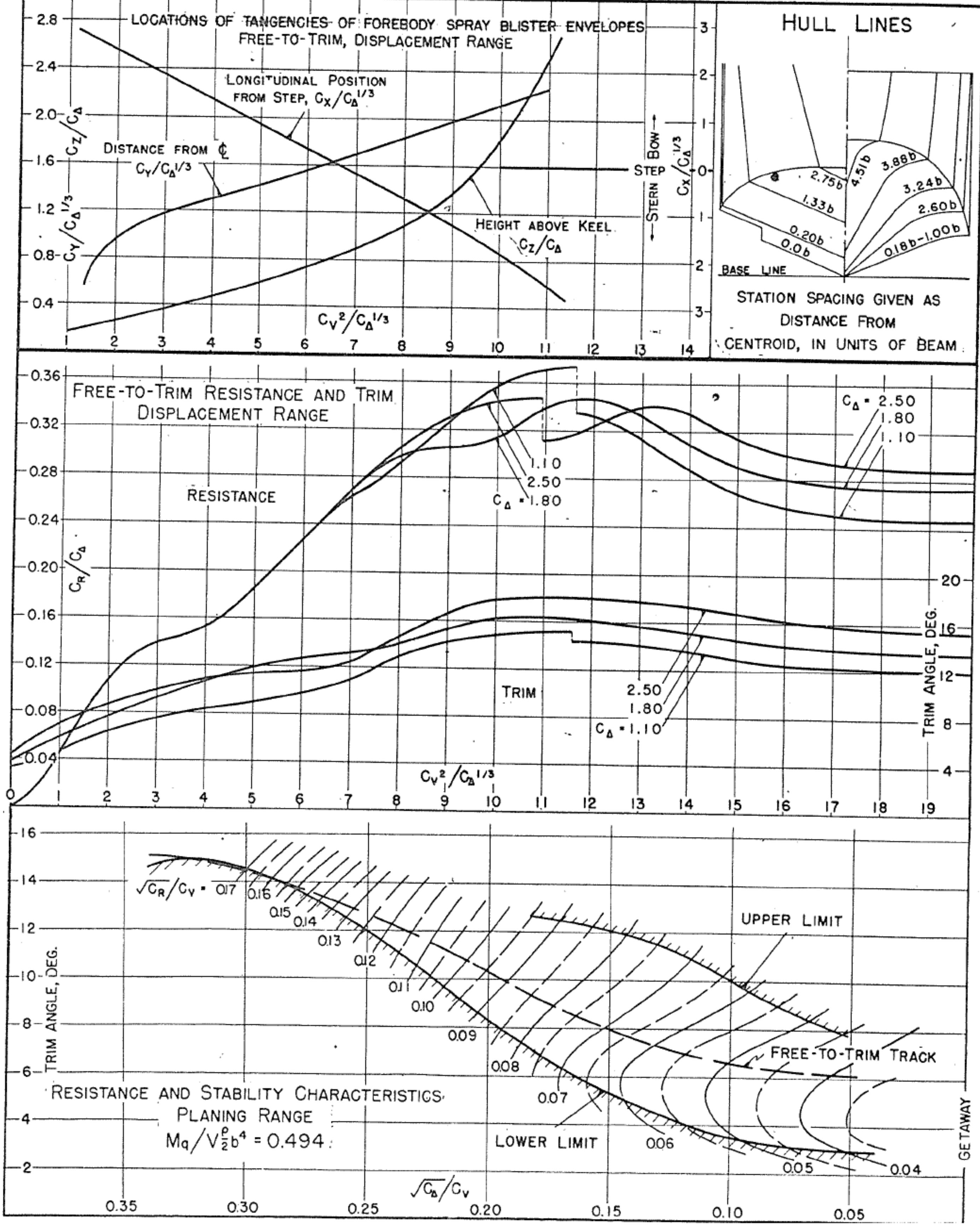
HOBOKEN, NEW JERSEY

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: DEC. 12, 1945 (REVISED) APRIL 19, 1945
MODEL BEAM: 5.40"
C.G. = 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL
C_{Δ_0} = 1.80 (NOMINAL)
k/L = 0.220
DESIGNATION: 8-61-8
MODEL NO. 644



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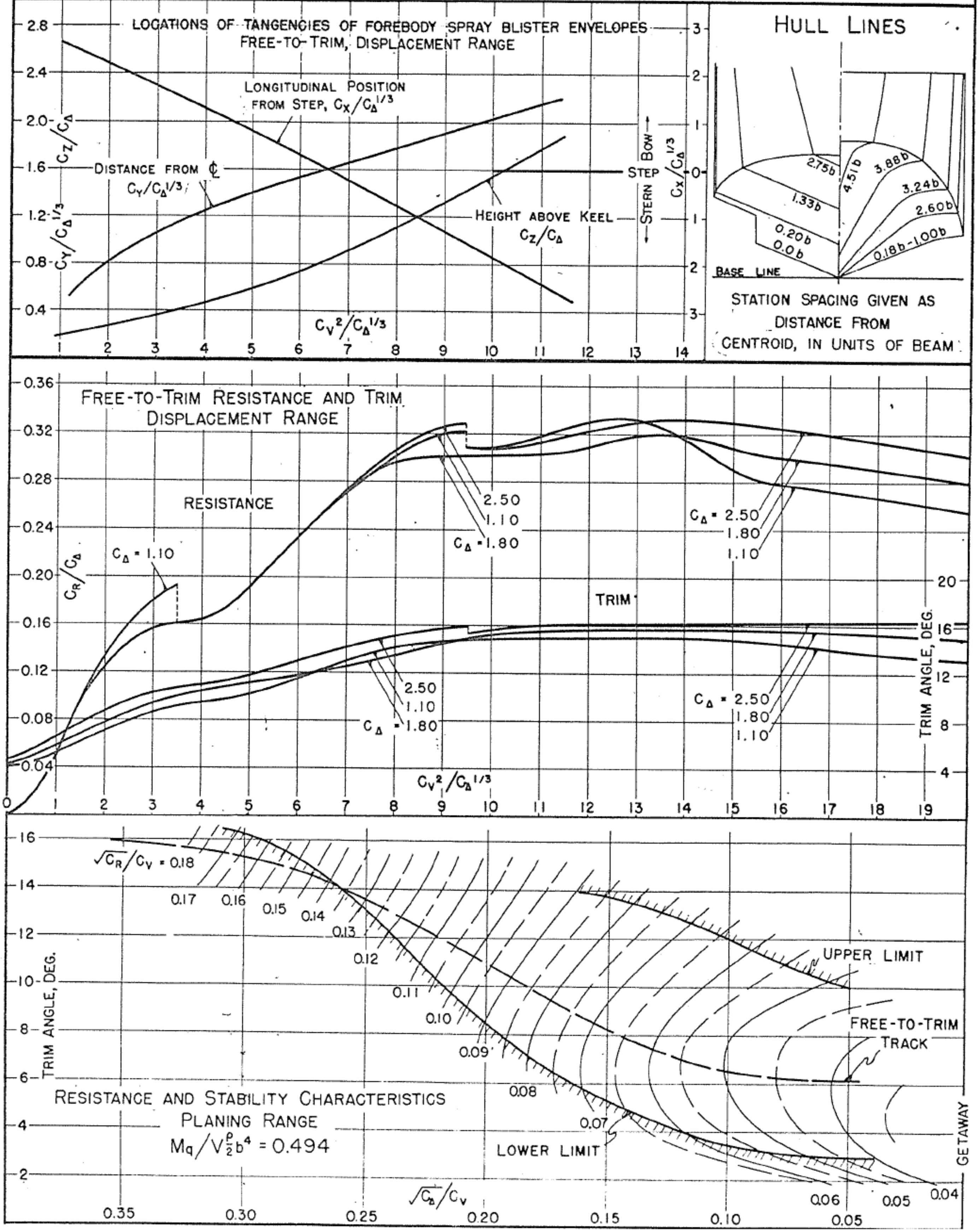
HOBOKEN, NEW JERSEY

R-31
-79-
N-24
-29

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: DEC. 12, 1945 (REVISED) APRIL 19, 1945
MODEL BEAM: 5.40"
C.G. = 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL
C_{Δ_0} = 1.80 (NOMINAL)
k/L = 0.220
DESIGNATION: 8-61-13.33
MODEL NO. 645



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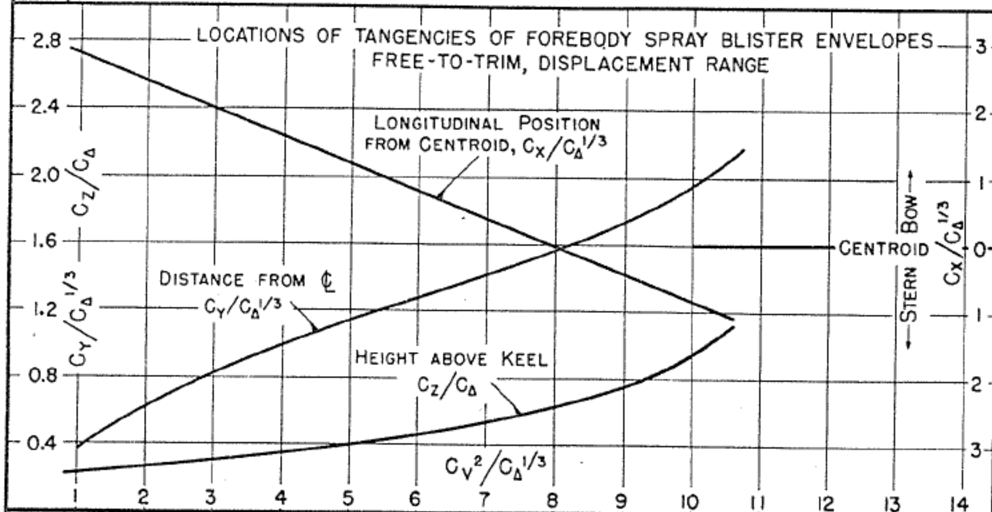
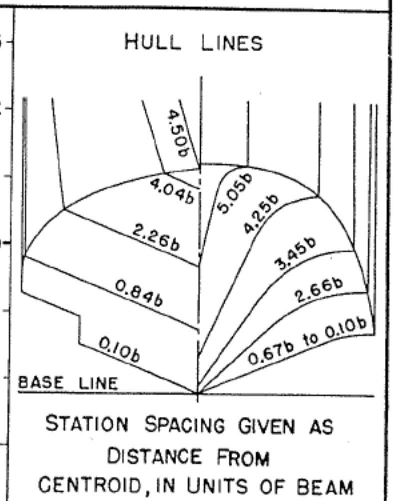
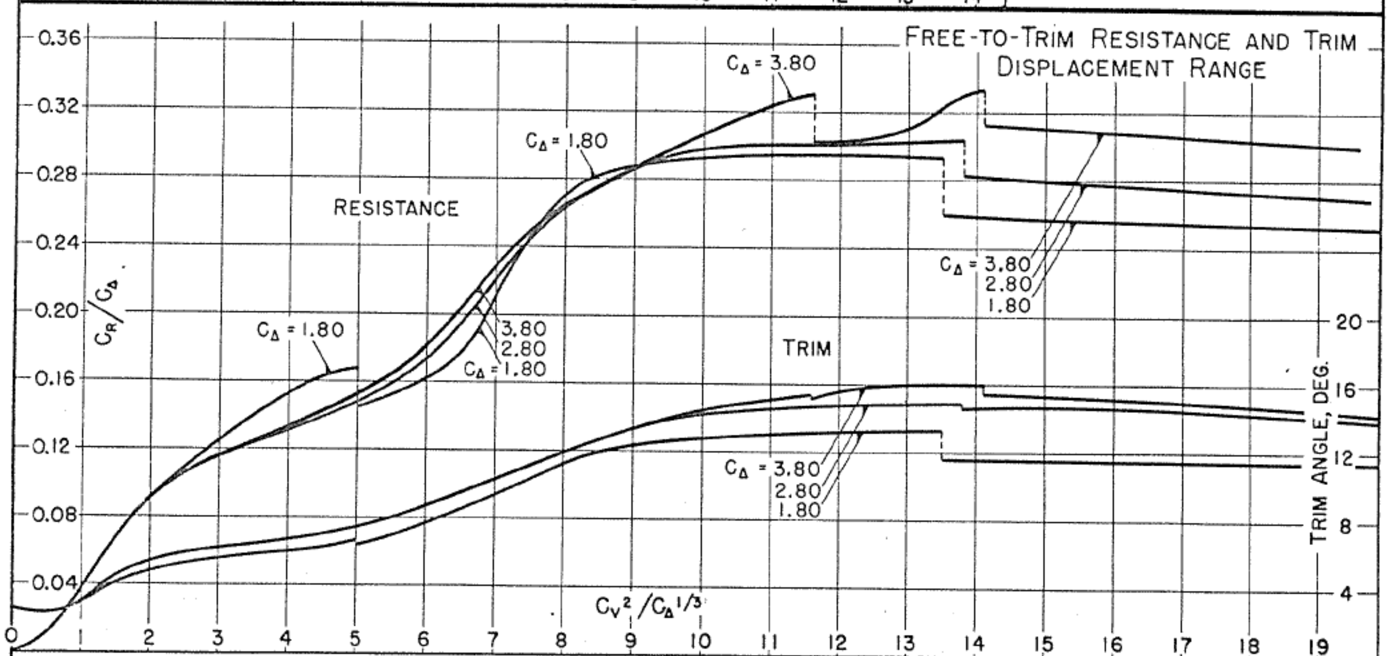
SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

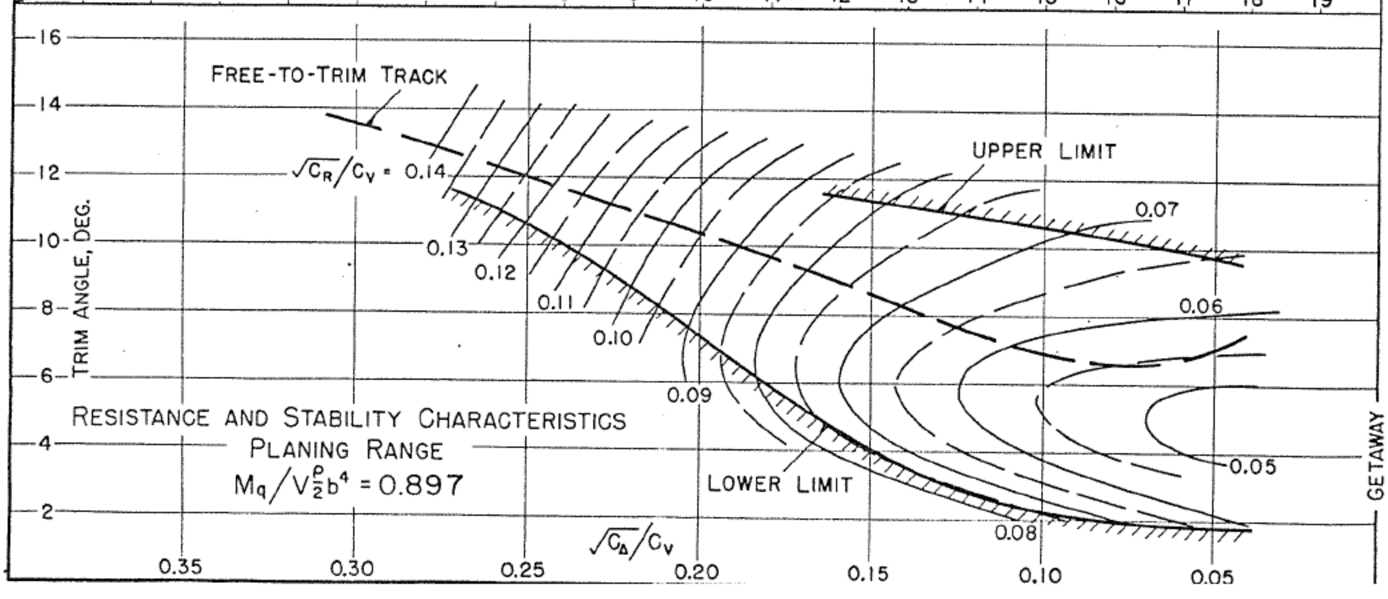
DATE: SEPT. 20, 1945 C.G.= 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL C_{Δ_0} = 2.80 (NOMINAL) k/L= 0.211 DESIGNATION: 10-55-10

MODEL BEAM: 5.40" MODEL NO. 674









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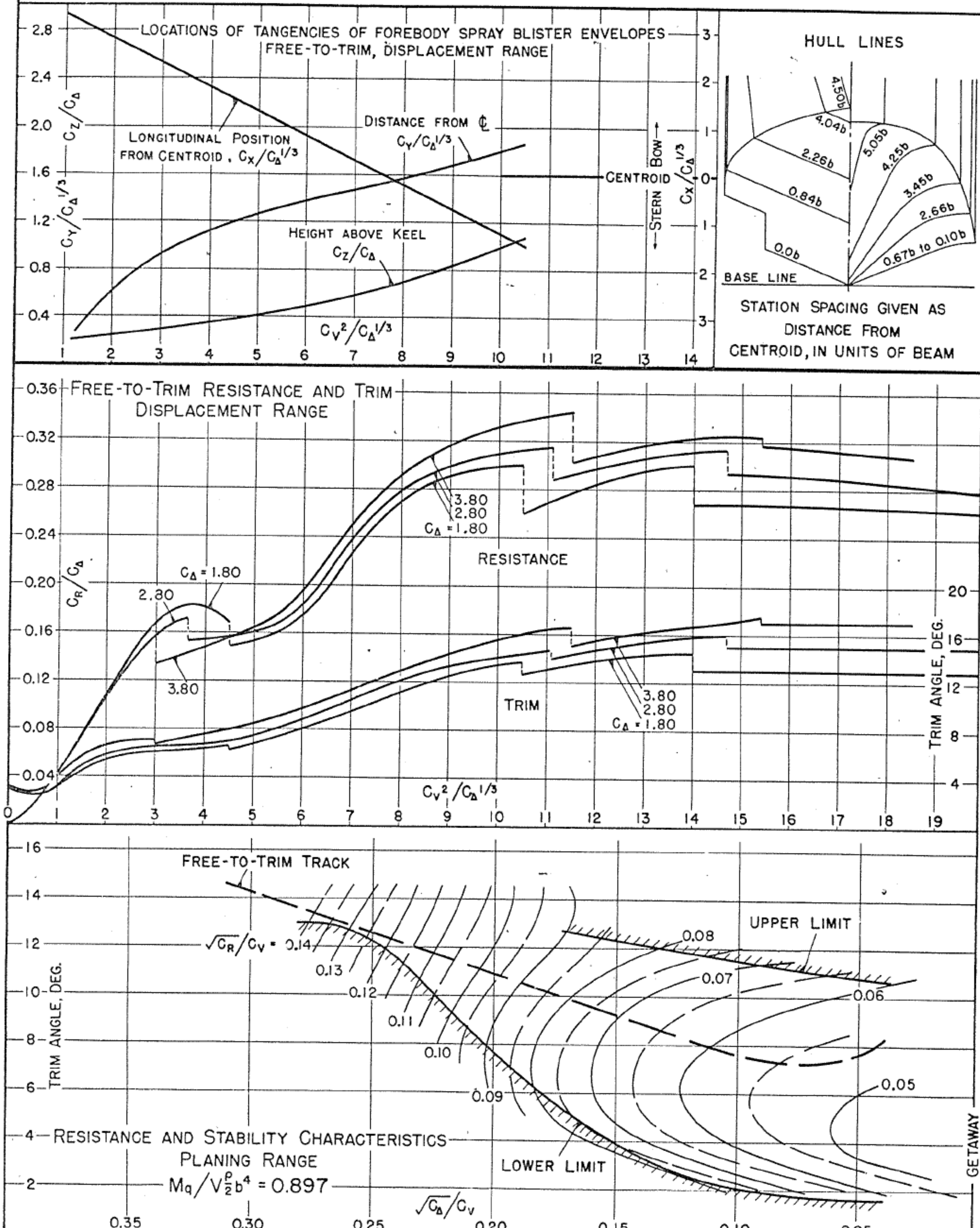
HOBOKEN, NEW JERSEY

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: JUNE 5, 1945
MODEL BEAM: 5.40"
C.G. = 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL
C_{Δ_0} = 2.80 (NOMINAL)
k/L = 0.211
DESIGNATION: 10-55-16.67
MODEL NO. 675



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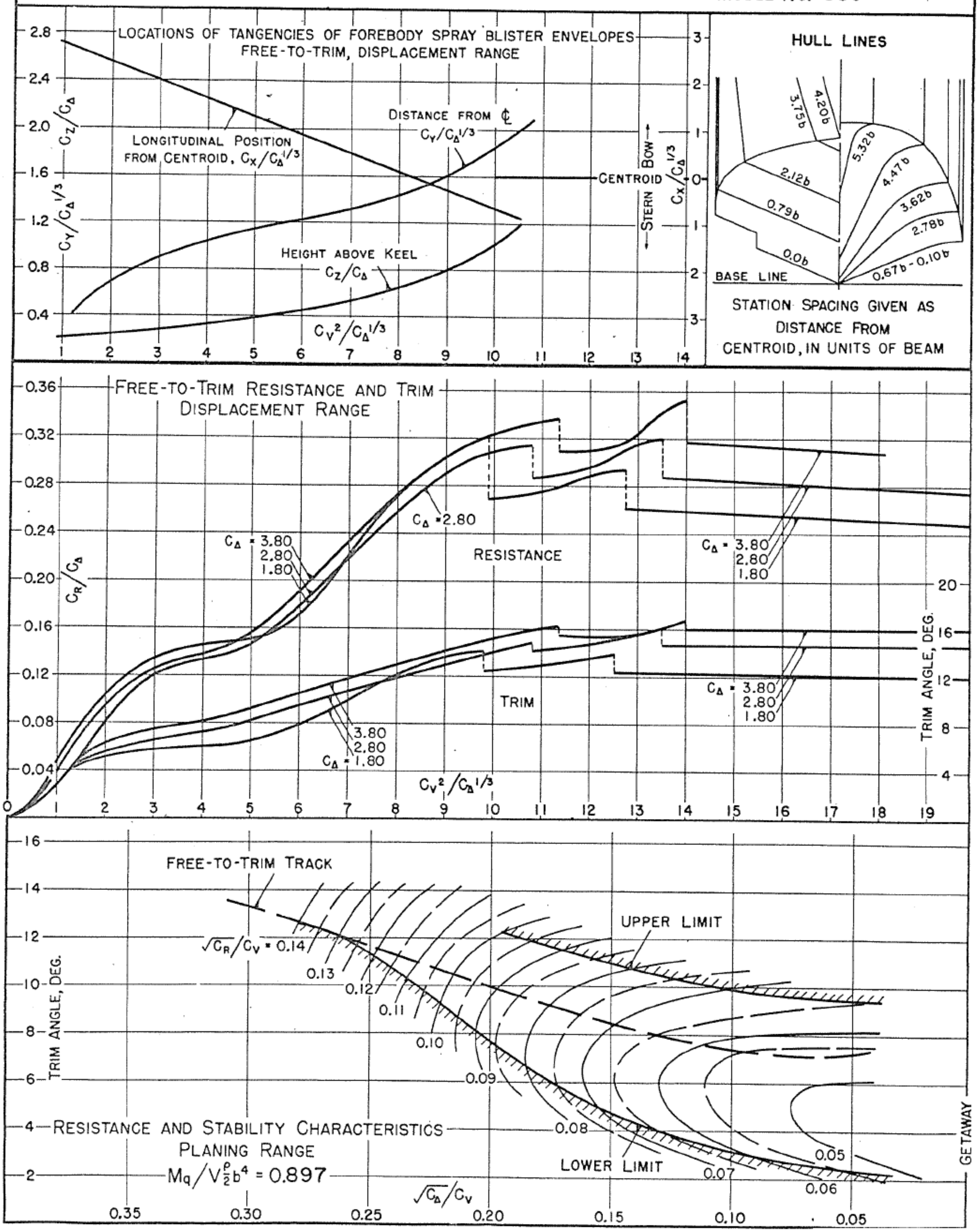
N-24
-71-
R-3
-82

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: JULY 28, 1945
MODEL BEAM: 5.40"
C.G.= 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL
C_{Δ_0} = 2.80 (NOMINAL)
k/L = 0.211
DESIGNATION: 10-58-10
MODEL NO. 689



N-24
-72-
R-31
-83

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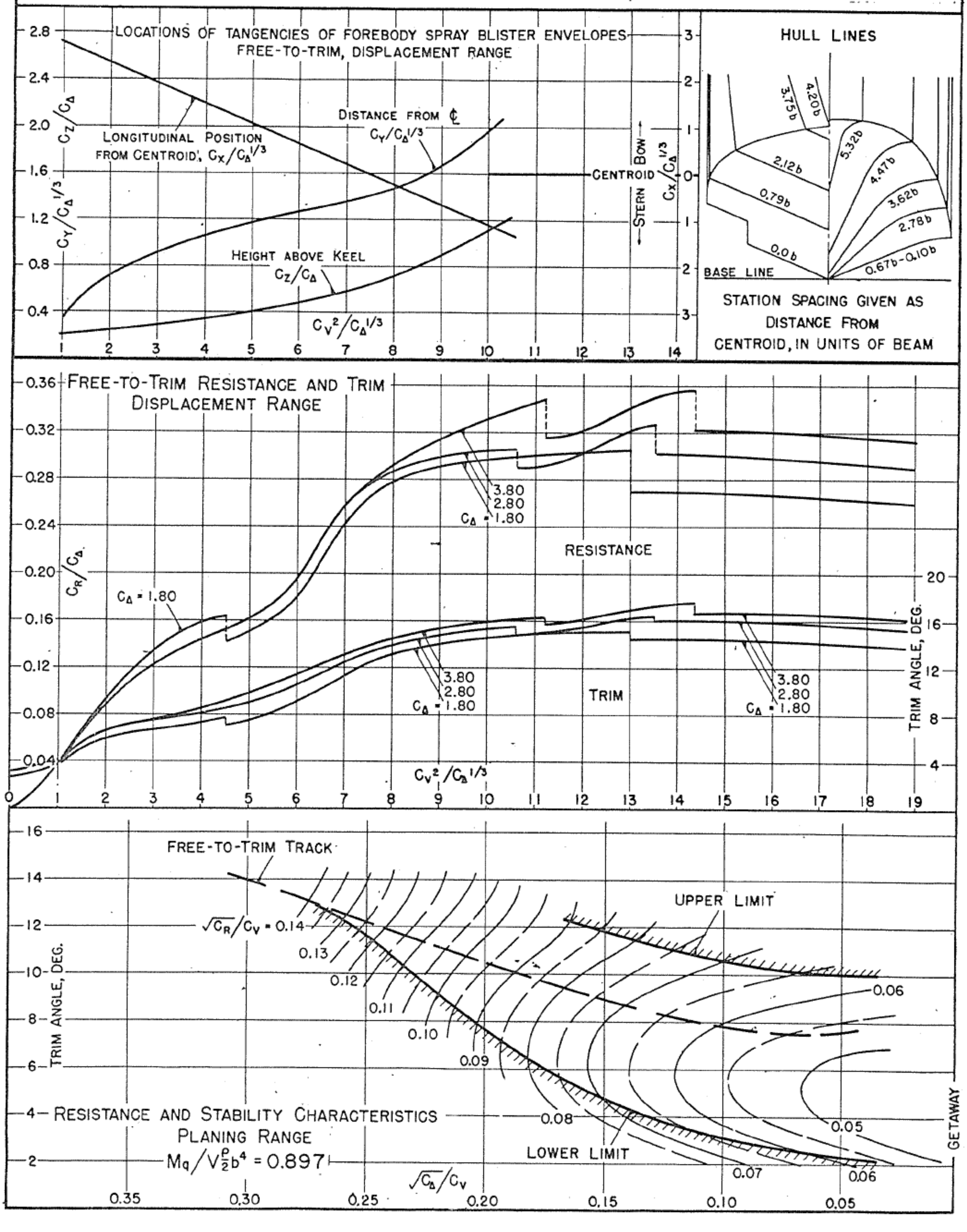
HOBOKEN, NEW JERSEY

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: AUG. 18, 1945
MODEL BEAM: 5.40"
C.G.= 0.35b FWD. OF CENTROID, 0.90b ABOVE KEEL
C_{Δ_0} = 2.80 (NOMINAL)
k/L = 0.211
DESIGNATION: 10-58-13.33
MODEL NO. 685



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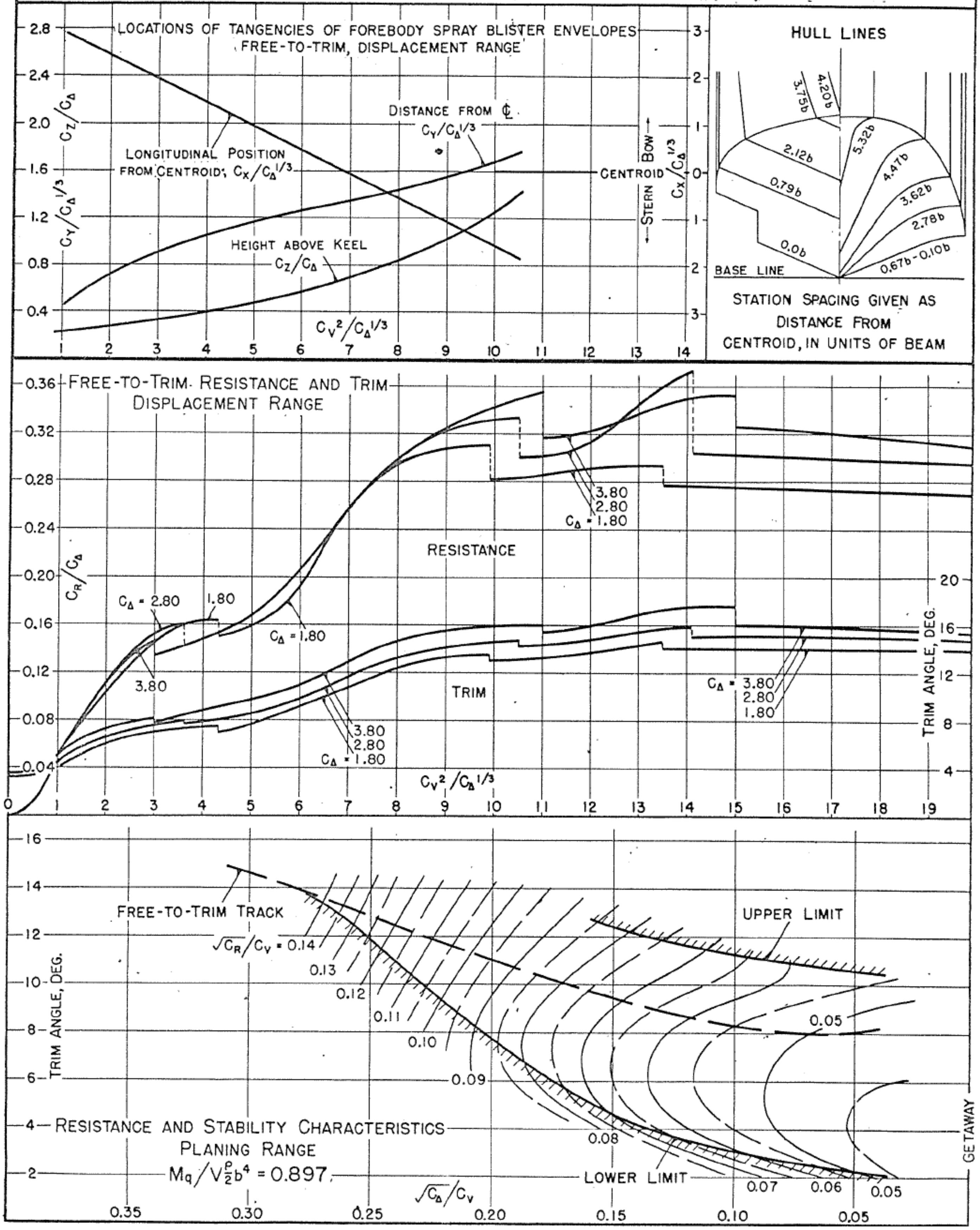
HOBOKEN, NEW JERSEY

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: JULY 16, 1945
MODEL BEAM: 5.40"
C.G.= 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL
C_{Δ_0} = 2.80 (NOMINAL)
k/L= 0.211
DESIGNATION: 10-58-16.67
MODEL No. 686



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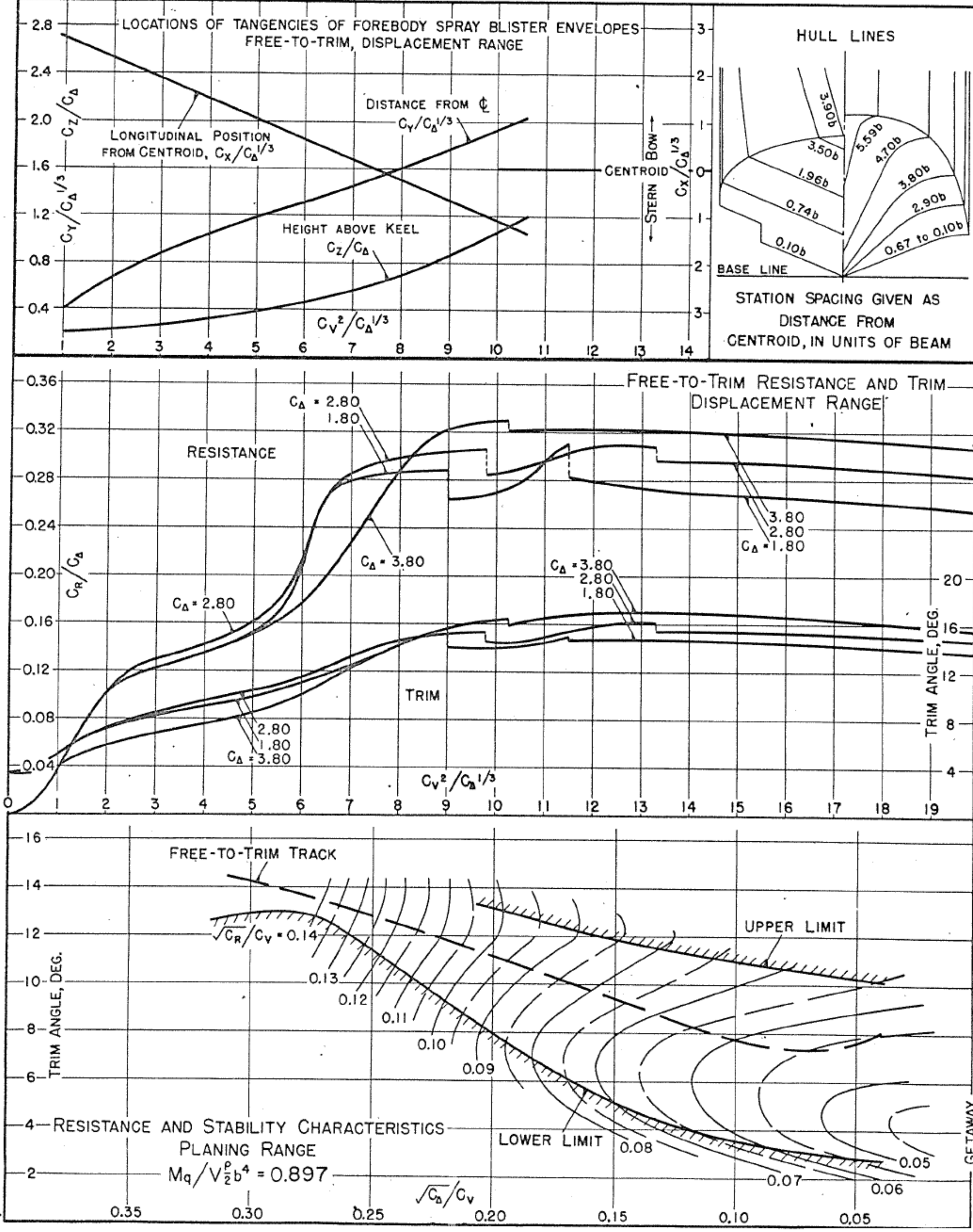
HOBOKEN, NEW JERSEY

N-24 -76- R-31 -85

SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: JULY 19, 1945 C.G.= 0.35 b FWD. OF CENTROID 0.90 b ABOVE KEEL C_{Δ_0} = 2.80 (NOMINAL) k/L= 0.211 DESIGNATION: 10-61-10
MODEL BEAM: 5.40" MODEL NO. 687



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SUMMARY CHART OF PRINCIPAL HYDRODYNAMIC CHARACTERISTICS

DATE: JULY 20, 1945 C.G.= 0.35 b FWD. OF CENTROID, 0.90 b ABOVE KEEL C_{Δ_0} = 2.80 (NOMINAL) DESIGNATION: 10-61-16.67

MODEL BEAM: 5.40" k/L = 0.211 MODEL No. 688